Spears or ploughshares : multiple indicators of activity related stress and social status in four Early Medieval populations from the North East of England

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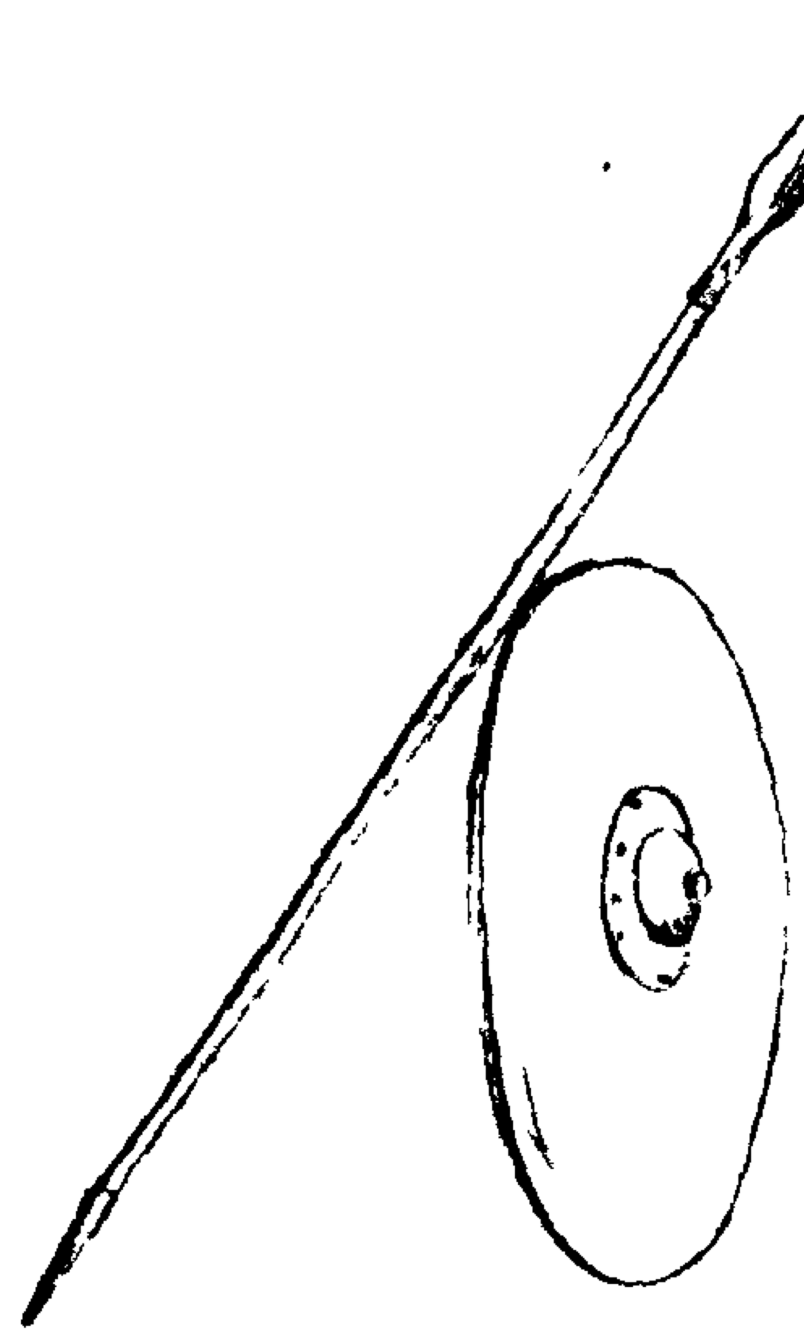

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By

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Declaration of Originality

I hereby declare that the research, data analysis, ideas and concepts presented within this thesis are original, unless referenced to other published works as indicated in the text. I also declare that none of the material contained in this thesis has been submitted to any other institution as part of the requirements for any other degree.

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Spears or Ploughshares: Multiple indicators of Activity Related Stress and Social Status in Four Early Medieval Populations from the North East of England

Abstract

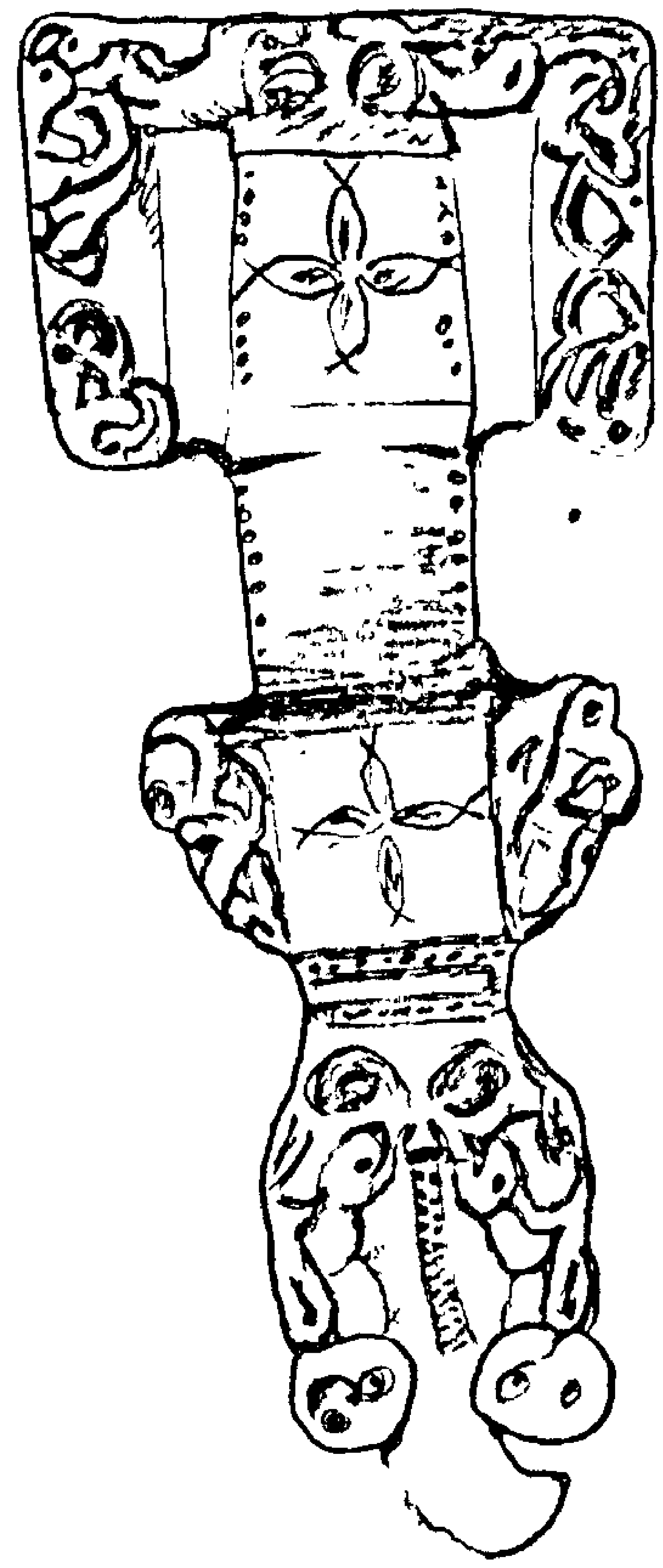
This study examines the patterns of musculoskeletal stress markers in four Early Medieval skeletal samples from the North East of England, and the relationship between these conditions and social status, as indicated by grave goods. Although social status in Early Medieval England has long been the subject of research, the question of how status was achieved is yet to be answered. Textual evidence and burial practices suggest that status may have been acquired through heredity and kinship, but it is also possible that the activities undertaken by an individual during life were important in defining status. The human skeletal remains from furnished Early Medieval cemeteries offer the possibility of examining patterns of skeletal change, which may be the result of physical activity, together with indicators of social stratification from burial practice.

This study examines the background to the study of markers of musculoskeletal stress (MSM) in archaeological skeletal samples, and clinical research into the aetiology and epidemiology of these changes. As the aetiology of conditions used as MSM in archaeological material is not fully understood, it is proposed that examining several different MSM will produce a more reliable results. In this study, osteoarthritis of the appendicular joints, enthesopathies, Schmorl's nodes and asymmetry in diaphyseal morphology of the paired humeri and femora are examined in adult skeletons from Castledyke South (Barton on Humber, Humberside), Norton Mill Lane (North Yorkshire), Bamburgh (Northumberland) and Norton Bishopsmill (North Yorkshire). The patterns of these changes are then interpreted in relation to burial practice at each of the four sites, and archaeological and documentary evidence for activity. This study shows that there are differences in the patterns of MSM between the status groups, and particularly between individuals that were buried with weapons and those buried with clothes fittings, suggesting that the level of activity undertaken during life may have been associated with social status.

"I grew up in a plain, and remained,
where earth and cloud fed me, until those who were my enemies
changed me, when I was old in years
from the natural state which I kept when alive,
altered my character, moved me from my home,
and contrived that contrary to my nature
I should often bow to the will of a slayer.
Now I am a torment in my master's hand,
.................a very great evil, if his courage is good.
or if my lord (will be) in quest of glory,
will exercise (his might), perform deeds of renown,
carry out.........
..................me moving from without, among the people,
....
and for injury......
..................dark shoulders girt round,
....
and a slender neck, and yellow sides
..................when the sun of battle
shines bright upon me, and (the warrior)
cherishes me well, and bears me into the foray
in his strong keeping. It is widely known
that among my bold comrades I, with the cunning of a thief....
within my head,........
sometimes, advancing , openly break into
a fortress that enjoyed security.
The warrior who knows my nature
goes in haste, speedy of movement,
away from that city. Say what I am called."

Riddle seventy-three, from the late 10^{th} century Exeter Book (from Mackie, 1934, pp 211-215)

Chapter One: Introduction



1: Introduction

1.1: Aims

In this study the possibility of a relationship between social status and physical activity is examined in adult skeletons from four Early Medieval populations from North East England. The rationale for choosing to study only adult individuals is that sub-adults may not have undertaken repetitive or habitual physical activities for long enough for changes to have taken place in the skeleton. Secondly the difficulty of assigning biological sex to sub-adults without the use of analysis of DNA prevents analysis of differences in activity between sex groups. The Early Medieval period has been chosen because during this time the dominant burial practice was inhumation in cemeteries, with the inclusion of grave goods. These cemeteries appear to have served single settlements and tend to produce large numbers of individuals, enabling valid population analysis and comparisons, and the application of statistical techniques to test the validity of any patterns of activity related change. Grave goods from Early Medieval cemeteries, dating between the 5^{th} and 8^{th} centuries, have been widely used as indicators of social status. Hence there is a potential that differences in status within and between populations can be compared with the findings of an osteological study. Social status was clearly an important aspect of people's lives in the Early Medieval period, the presence of different ranks in society is indicated in documentary sources and suggested by variations in burial practice (Chadwick, 1924; Stenton, 1971; Härke, 1997), but it is not clear how status was acquired. It is proposed that there will be a relationship between social status and levels of physical activity as indicated by changes in the skeleton associated with physical activity. These changes, known as "markers of occupational stress" (MOS) (Ronchese, 1948) or "musculoskeletal stress markers" (MSM) (Hawkey and Merbs, 1995), include pathological and non-pathological conditions such as enthesopathies, asymmetry in limb size and shape, Schmorl's nodes, and osteoarthritis (OA).

The original use of the term "markers of occupational stress" or MOS is attributed to Francesco Ronchese of the Boston University of Medicine (Ronchese, 1948), and it has become widely used in the field of physical anthropology. However, the use of this term can be misleading as it places emphasis on *occupation*, i.e. a specific task or career, carried out or followed by the individual, rather than changes that reflect patterns of activity over a lifetime, that may be unrelated to specific occupations. The term "musculoskeletal stress markers" (MSM) may be preferable, as it does not have the same connotations relating to the identification of specific occupations as "MOS". In some studies the term "musculoskeletal stress markers" is used specifically to describe enthesopathies (Munson Chapman, 1997, Peterson, 1998, Weiss, 2003, Wilczak, 1998), but in this study the term will be used as shorthand for all the conditions mentioned above. Clinical and archaeological studies have related the development of these individual conditions to specific and general patterns of activity (Claudepierre and Voisin, 2005, Croft *et al.*, 1992, Felson, 1994, Hawkey and Merbs, 1995, Jones *et al.*, 1977, Peterson, 1998, Shrier, 2004, Stirland and Waldron, 1997). However, due to the complex aetiologies of these conditions, it is proposed that an approach using multiple indicators will produce a more reliable interpretation of the levels of activity that individuals were undertaking. It is possible that the MSM that will be examined may each indicate different types of activity, and hence these findings will add to the understanding of MSM in archaeological populations.

Musculoskeletal stress markers are thought to develop as the result of repetitive or excessive activity that is begun at a young age, and continued throughout life. Activities that have been suggested as causes of activity related stress in archaeological populations include archery and weapon use (Peterson, 1998, Schmitt *et al.*, 2003, Stirland, 2000), rowing (Lai and Lovell, 1992), weaving (Groves, 2001, Kennedy, 1989) and a variety of agricultural and subsistence activities (Bridges, 1989, Bridges, 1991, Dutour, 1986). However, these conditions and skeletal changes can also be caused by other factors including age, injury and disease. If MSM are observed in young, otherwise normal individuals it may be possible to infer some kind of physical activity as a cause. In this study the patterns of MSM seen in adults of different ages will be compared to identify any patterns in the frequency of MSM that may be associated with age. Analysis of the skeletal remains will include assessment of the age, sex and general state of health of each individual, together with a more detailed macroscopic examination for the presence of any MSM.

In the past there has been a tendency to neglect the human remains excavated from Early Medieval sites in favour of the study of material culture. This attitude is most apparent in site reports, particularly those dating from before the 1980s. In most early site reports, where analysis of the skeletal material had taken place, the report tends to be brief, uninformative and, in the worst cases, confined to microfiche. The Sewerby site report, (Hirst, 1985) which consists of 178 pages and two microfiche, devotes fewer than 2 pages of the report to the analysis of the skeletal material. This widespread attitude towards the human material may have been the result of the presence of artefacts of material and cultural value in the form of grave goods in some of the burials, and the need to preserve and report these items outweighing the need to fully examine the skeletal material. There may also have been a simple lack of understanding of the wealth of information that can be gathered from human remains. It is suggested that a great deal of valuable information regarding the life-ways of Early Medieval people can be discovered by analysis of skeletal remains, information that has the potential to greatly enhance the data gathered from material culture. Examination of several populations from the same region may highlight similarities and differences in lifestyle, possibly resulting from the status of the population, and consequently this study examines skeletal material from four populations from the North East of England.

The data generated from the study of the biological material is interpreted using archaeological and documentary evidence of activity, and in relation to the status of the individuals and populations as implied by the status of the site, and the burial practices associated with the individual. This highlights any potential relationships between status and the type and level of activity undertaken. Statistical analyses are used to evaluate the significance of any patterns of MSM that may be observed. By comparing these data with the findings of clinical studies of activity related conditions and with the results of other archaeological studies, an indication of the validity of the conclusions, and similarities and differences between modern populations and people in the past will be assessed.

In summary, the aims of this study are:

- To identify patterns of skeletal change that may be associated with physical activity in four skeletal samples from the North East of England
- To examine how these changes relate to differences in social status as indicated by burial practice
- To explore the validity of the use of skeletal changes as evidence of lifestyle and activity
- To gain an insight into the lifestyle and social structure of people living in the North East of England during the Early Medieval period.

The hypothesis to be tested is that there is a relationship between social status as expressed through burial practices and levels of physical activity in Early Medieval England, as indicated by skeletal changes.

1.2: Why attempt to reconstruct physical activity from the skeleton?

The scientific analysis of archaeological human remains can reveal a great deal of information about the past. Isotopic analysis of dental enamel can indicate the kind of diet people were eating, where they grew up and if they moved to live in a different area as a child (Beard and Johnson, 2000). Analysis of ancient DNA can identify biological sex, reveal familial relationships and indicate the presence of disease (White, 2000). A wide variety of diseases, dietary deficiencies and injuries leave their mark on the bones and teeth, and the trained observer can identify these changes and hypothesise as to the environmental and social implications (see below for a discussion of some of the conditions and changes observed in archaeological human remains). The reasons for undertaking this kind of research are obvious; to add to the knowledge gained through archaeological and historical investigation, and also it is the desire to bring the populations of the past back to life, as Jurmain says, "to make them 'real people'" (1999, pp 2).

Current research into the possibility of recognising occupational stress in the human skeleton is the result of a "synthesis between industrial medicine and physical anthropology" (Kennedy 1989, pp 131). The study of possible markers of occupational stress had its origins in the 16th century, with the beginnings of industrial medicine. In 1556 Georgius Agricola published a study of mining that included accounts of the diseases and injuries that miners were prone to. The study of industrial medicine flourished, and by the 19th century, anatomists realized that a wide range of changes and irregularities in the skeleton could be the result of activities related to physical activity and occupation. At the same time, scholars began to examine the anatomical differences between modern humans and prehistoric hominids. These scholars noted that features such as squatting facets and platycnemia were more frequent in hominids and apes than in modern humans, and related this observation to differences in lifestyle (Kennedy, 1989).

In 1892, Julius Wolff stated that; "every particle of mature bone is very active. Such activity must appear in the external shape of the bones" (Wolff 1892 pp 78). This law has been integral to the development of behavioural inference from the skeleton, and the majority of modern studies are based around this concept, referred to as "Wolff's Law". More recently, researchers have applied mechanical principles to the study of the effects of physical activity on bone, resulting in the development of archaeological biomechanics (Jurmain, 1999). In particular, the principles of cross-sectional geometry have been applied to long bone shafts, resulting in an apparently reliable method of assessing asymmetry and differences in robusticity (Knüsel, 2000, Rhodes and Knüsel, 2005, Trinkaus *et al.*, 1994).

Occupational medicine is now one of the major areas of modern clinical research, primarily due to the debilitating nature of some activity-induced diseases. Back pain as the result of occupation related activity is considered to be one of the main causes of lost working hours, and up to 80% of adults experience back pain at some point in their lives (Felson, 2001). The clinical data relating to markers of occupational stress records a vast number of conditions ranging from "equestrian's buttocks" to "dog-walker's elbow" (Kennedy, 1989) as well as the more common degenerative joint diseases and traumatic injuries. Clinical research has also focussed upon asymmetry in the size and shape of the long bones resulting from activity related stresses upon the bone (Jones *et al.*, 1977, Pearson and Lieberman, 2004). While some of these biomechanical studies are related to the impact of repetitive activity and handedness, the majority of work in this area falls into the realm of sports medicine. Sports medicine also deals with a number of conditions that are the result of repetitive activity or specific forms of trauma, and consequently clinical studies of professional athletes are the most frequently used analogies for archaeological populations.

In order to attempt to reconstruct patterns of physical activity from the skeleton it is essential to have an understanding of the conditions used as MSM and their potential advantages and disadvantages as indicators of physical activity. The following sections will review the types of changes that are most commonly used as markers of physical activity in archaeological skeletal samples, and the findings of preceding studies of MSM will be examined. In Section 1.4 the clinical literature relating to the specific changes that are examined in the present study will be reviewed, as will the variety of methods used to identify these conditions and changes in archaeological skeletal material.

1.3: Archaeological studies of physical activity

The conditions that are most commonly studied in archaeological populations in relation to physical activity are; dental wear, degenerative changes to the joints, enthesopathies, long bone asymmetry, robusticity and biomechanical analysis of long bones, and trauma. These markers of occupational stress have all been used with varying degrees of success and reliability, to infer patterns of activity in archaeological populations.

1.3.1: Dental Changes

Patterns of wear in the teeth can provide information about the type of diet eaten by archaeological populations and the age of the individual (Brothwell, 1989, Brothwell, 1963), but occasionally abnormal or extreme degrees of wear are seen. Some populations are known to have habitually modified their teeth for cultural purposes by reshaping the teeth or adding decorative insets (Larsen, 1997), but it is possible that some changes to the teeth and variations in wear may indicate aspects of behaviour and occupation. Transverse grooves have been noted on the occlusal surfaces of mandibular incisors and canines in several prehistoric North American populations. This pattern of dental wear has been interpreted as the result of processing sinews for cord or bowstrings, or plant fibres for basket weaving. This interpretation is supported by ethnographic evidence from Greenland Eskimo and North American Panamint populations (Larsen, 1997). It is also thought that these changes may be the result of holding strings in the mouth during the production of fishing nets. Other dental changes can be caused by habitual pipe smoking, resulting in notches between the anterior teeth, and repeated use of a toothpick, leading to distinctive grooves (Hillson, 2000, Willey and Hofman, 1994). However, the extreme degree of wear seen in the dentition of many Early Medieval populations could obscure behaviour related changes to the teeth, as could the presence of calculus deposits, thus reducing the opportunity to identify behaviourally related changes in the teeth.

1.3.2: Degenerative Joint Disease and Osteoarthritis

Degenerative joint disease (DJD) is an umbrella term for many conditions affecting the joints, but in archaeological material the majority of studies of physical activity relate to osteoarthritis, a condition that specifically affects the synovial joints. For example, extensive studies of the skeletons of Sadlermiut Eskimo from the Northwest Territories, Canada undertaken by Merbs (1983) led to the observation of a pattern of arthritic change which appears to have been closely related to habitual activity. Adult males frequently had osteoarthritis of both acromio-clavicular joints, and highly developed arm muscles, a combination that was most likely to be caused by kayaking. In contrast, adult females had a high frequency of severe degenerative changes in the temporomandibular joint. Ethnographic evidence records that the women regularly softened leather and animal hides by chewing them, thus placing repeated extra stresses on the joints of the jaw (Merbs, 1983). In this case, the recognition of the significance of the patterns of arthritic change was aided by the fact that there were records of the habitual activities of the population. Unfortunately this is not usually the case with most archaeological populations so the patterns of DJD can only be related to broad changes in lifestyle.

Throughout the late 1980's and 1990's a flurry of studies attempting to relate patterns of osteoarthritis to physical activity appeared, particularly in relation to transitions between one type of subsistence activity to another, and particularly agriculture (Cohen and Armelagos, 1984), leading to a variety of different conclusions. For example, a study of Indians from Southern California over a period of time when subsistence activities changed from primarily land based hunter-gathering to more exploitation of maritime resources found that there was a decrease in the severity of osteoarthritis in the vertebral column in females, but an increase in osteoarthritis (OA) in the vertebral column in males between the two periods (Walker and Holliman, 1989). These variations were interpreted as being indicative of a division of labour between the sexes, and an increase in the levels of physical stresses experienced by males in the transition to a more fishing based economy (Walker and Holliman, 1989).

Jurmain (1990) compared the patterns of osteoarthritis in skeletons from the south-eastern San Francisco Bay area dating from AD 500 to pre-European contact, with comparable agricultural communities. This study showed that the pre-agriculture group had more joint disease than the agricultural groups, indicating that the hunter-gatherer lifestyle placed greater stresses on the joints (Jurmain, 1990). In contrast, a series of studies by Bridges (1989, 1991) indicated that agriculturalists (AD 1200-1500) in north-east Alabama might have had a 'harder' life than the preceding hunter-gatherer population (6000-1000 BC) with an increased workload, based upon patterns of osteoarthritis and comparisons of bone density (Bridges, 1989, Bridges, 1991). The apparent contradictions of the results of these studies highlight some of the problems with osteoarthritis as a marker of activity related stress. The clinical research discussed in Section 1.4 indicates that, in some cases, osteoarthritis is most likely to be the result of wear and tear on the joint, but that there are also many other factors that are implicated in the development of the condition. Consequently it is possible that there could be another factor such as a genetic predisposition for the condition in a population, a nutritional deficiency, a difference in the pattern of trauma in the populations, or even an environmental factor such as the type of landscape over which the people were moving, resulting in more joint stress. It is also possible that Jurmain and Bridges used different criteria for identifying osteoarthritis. The identification of joint disease in archaeological skeletal material is notoriously subjective (Rogers and Waldron, 1995), and is not helped by the limited medical understanding of the condition at present (McKinley and Bay, 2003). This issue will be discussed in more depth in Section 1.4.

In addition to the studies that have utilized patterns of osteoarthritis to explore population trends in physical activity, many studies have attempted to relate patterns of OA in skeletal material to specific activities and occupations. Molleson interpreted the patterns of OA in the vertebral columns and feet of Neolithic agriculturalists as being indicative of the stresses inflicted upon the body whilst kneeling to grind grain (Molleson, 1989). The pattern of OA in the vertebral columns of women from Ensay in the Outer Hebrides was related to habitual carrying of heavy loads on the back using baskets, which resulted in a characteristic posture and alteration to the normal contours of the vertebral column, leading to variations in the vertebrae affected by OA (Sofaer Derevenski, 2000).

Osteoarthritis of the elbow has also been related to a variety of different activities including atlatl (spear-thrower) use (Angel, 1966, Ortner, 1968), and the study of Californian Indians mentioned above related severe OA of the elbow and wrist in males to the use of harpoons and spears for fishing (Walker and Holliman, 1989). A study of skeletal material from 120 slaves from 18th, 19th and early 20th century sites from Maryland, Virginia and the Carolinas related the patterns of arthritis seen to a variety of activities including digging for ore and pounding iron (Kelley and Angel, 1987), but in essence this study is a series of anecdotal cases rather than a rigorous comparison of the changes seen in the bodies of slaves with other less "hard working" populations. A similar study of the free black community from Philadelphia related patterns of spinal osteoarthritis to occupations involving horseriding (Angel *et al.*, 1987). The anecdotal nature of these and other similar studies has been a hindrance to the development of the study and interpretation of MSM. The tenuous connections between the patterns of arthritic changes seen in individuals in many of these studies are not supported by the clinical literature, and yet are often assumed to be "fact" by other researchers. This leads to circular arguments; a certain pattern of OA has been related to a specific activity, and hence where it is seen in other populations it must indicate that that activity was carried out. This is a dangerous assumption and reference to anecdotal studies as explanation for the patterns of changes seen should be avoided wherever possible. Instead, clinical studies of OA where the involvement of the patients in habitual, sporting or occupational activities is known should be the primary source for the osteologist interested in interpreting the patterns of OA that are observed in archaeological material.

The skeletal sample from the 18th – 19th century Christchurch Spitalfields cemetery in London provided the opportunity to examine patterns of OA in individuals of known occupation, with varied results. A study of the patterns of OA amongst individuals known to have been weavers did not find any connection between weaving and the development of unusual patterns of OA in males. However almost all the men in the sample were master weavers who may not have used a loom for many years, and may instead have been managing other workers (Molleson and Cox, 1993). In a comparison between the manual and non-manual workers, only the difference in the frequency of OA of the vertebral column was found to be statistically significant between the two groups, but the cause of this difference remains unknown (Waldron, 1993). Although the occupation of some of the individuals was recorded, there is no way of knowing when they started work, how long they were working on specific occupations and what proportion of their physical activity occupational activities represent.

More recently, there have been few studies that have examined osteoarthritis in isolation as an indicator of activity related stress, as osteologists have become more critical of the theoretical relationships between OA and physical activity. Instead, other bone changes such as enthesopathies have become more favoured as potential markers of activity related stress, although these conditions are not without their own problems, as will be discussed in Section 1.4. Other joint changes have also drawn the attention of researchers; in a recent paper Mays (2005) investigated the frequency of supra-acetabular cysts in adults who were not affected by osteoarthritis of the hip, from the Medieval British site of Wharram Percy. Mays found that 13% of the individuals examined had supra-acetabular cysts without the presence of osteoarthritis, no changes were seen in the femoral head in any cases, and a statistically significant bias towards involvement of the right side was identified (Mays, 2005). Although the aetiology of these lesions is uncertain, the author suggested that they may be the result of trauma to the hip joint, particularly fractures of the acetabular rim, or tears to the base of the acetabular labrum, a cartilaginous extension of the acetabular rim. Furthermore, it was suggested that the apparently high proportion of these lesions at Wharram Percy in comparison with modern populations, may have been the result of strenuous activity such as ploughing, carting and felling trees (Mays, 2005). Although osteoarthritis may have fallen out of favour recently as a marker of activity related stress (Jurmain, 1999), it is clear that patterns of joint pathology are still considered an avenue worth exploring, albeit with caution and with reference to clinical research.

1.3.3: Schmorl's Nodes

Archaeological studies of Schmorl's nodes (SN) are not as frequent as some of the other conditions used as indicators of activity related stress, and Jurmain has argued that the high frequency of Schmorl's nodes in modern populations could indicate that they are a "normal" feature of the vertebrae, rather than a pathological lesion (Jurmain 1999, pp166). However interest in the use of this condition as a marker of activity related stress is on the increase, and several studies have examined patterns of Schmorl's nodes in archaeological material.

In a study of the vertebral column from the Chapelle-aux-Saints 1 Neanderthal, discovered in France, Schmorl's nodes were recoded together with other degenerative changes, and the pattern of changes was compared with those seen in clinical and archaeological studies of modern humans (Dawson and Trinkaus, 1997). Unfortunately, this study recorded SN simply as being a grade of degeneration of the vertebral surface, together with eburnation, rather than as a separate lesion, thus preventing direct comparison of the patterns of SN in the Neanderthal vertebral column with any other studies. The levels of changes (including SN) seen in the Neanderthal vertebral column were interpreted as being indicative of a "pattern of activity-related trauma" (Dawson and Trinkhaus, 1997 pp 1020), possibly burden carrying. As this conclusion is drawn from the incomplete vertebral column of a single (probably elderly) individual, it is not realistic to attribute the changes seen to any specific pattern of activity, nor to use this single individual to identify differences in activity between Neanderthals and anatomically modern humans.

Angel suggested that Schmorl's nodes were the result of sudden movement and heavy lifting (Angel, 1971), and comparisons of the frequency of these lesions and the locations affected within the vertebral column have been used to try to identify differences in patters of activity within and between populations. In a comparison of the location of SN in the vertebral columns of males from the Tudor warship, the Mary Rose, recovered from the English Channel, and males from an almost contemporary Medieval cemetery site from Norwich, SN were more concentrated in the middle region of the Mary Rose vertebral columns, while in the Norwich skeletons all regions of the vertebral column were affected (Stirland and Waldron, 1997). The authors of this study related the differences seen in patterns of spinal change between the two samples to differences in activity patterns, particularly the stresses of undertaking heavy work within the confines of a Medieval ship, but did not give any specific explanations for the differences seen in the patterns of Schmorl's nodes.

The study carried out by Robb *et al* (2001) on a sample from Iron Age Italy examined patterns of Schmorl's nodes, amongst indicators of physical and nutritional stress, together with indicators of social status from grave goods, to try to identify relationships between health, activity and social status. In this study there was a weak correlation between low levels of SN in females and the presence of non-pottery items (primarily ornaments) in the grave, and amongst males SN were inversely related to the presence of weapons, while males with no grave goods had a high prevalence of SN (Robb *et al.*, 2001). Robb *et al* related the differences in the patterns of SN between the different status groups to differences in quality of life and levels of physical stress, but did not cite any specific activities as causes other than the possibility of generally higher levels of labour amongst individuals with no grave goods. The authors also stressed the need to place studies of MSM, health and status firmly within an appropriate social and historical context as "which skeletal features emerge as socially significant depends on the locally specific nature of the biological stresses and their social allocation" (Robb *et al* 2001, pp 220).

1.3.4: Enthesopathies

Enthesopathies have become increasingly widely used as indicators of levels of physical activity in recent years, as the development of these bony changes to the entheses has been connected to physical exercise in clinical and sports medicine studies (Kennedy, 1989, Peterson, 2000). The popularity of these lesions as potential markers of activity related stress is reflected in the wide range of studies which have used enthesopathies, either alone or in combination with other skeletal changes, to attempt to reconstruct the behaviour of populations in the past.

One of the first studies to relate the presence of enthesopathies to patterns of physical activity was that carried out by Dutour (1986), and this study is the most frequently referenced in subsequent research into the prevalence of these changes in archaeological material. Dutour examined two Neolithic Saharan skeletal samples, 25 skeletons from one site and 16 from a second site, all of which were adults with long bones present, and found that 22% of the skeletons examined had one or more enthesopathies present (Dutour, 1986). Dutour reviewed the locations of the enthesopathies that were observed, and suggested possible causes apparently drawn from clinical data, including javelin throwing, wood cutting, carrying heavy loads with bent elbows and long distance running, although references were not given for the majority of these clinical "examples". These observations were then related to activities which the populations in question may have carried out including fishing with harpoons and nets at one site and running over stony ground in the other (Dutour, 1986).

Although the findings of this work have been widely cited in support of other studies of enthesopathies in archaeological material, this study is flawed in several ways. The number of individuals examined was small, and in both samples a large proportion of the skeletons could not be sexed, limiting the value of the sexual variation in the patterns of lesions that Dutour reported. The age ranges of the samples are not given and, as enthesopathies tend to increase with age (Benjamin and McGonagle, 2001), it is possible that the differences noted between the two skeletal samples are due to one sample having a greater proportion of older individuals than the other. Furthermore, the enthesopathies that are then related to specific activities are seen in very few individuals (one or two cases for each enthesopathy mentioned), so these single cases are more likely to indicate single incidences of trauma, rather than population level patterns of activity. The paucity of references to clinical studies of enthesopathies of known cause reduces this work to a catalogue of anecdotes rather than a scientific study of changes that can then be applied to a whole population. Despite its flaws, the work carried out by Dutour sparked a wide range of further studies using enthesopathies as indicators of activity related stress, exploring specific activities (Peterson, 1998, Steen and Lane, 1998), patterns of economic activity (Churchill and Morris, 1998, Eshed *et al.*, 2004, Munson Chapman, 1997), and even the impact of disability upon the "activity patterns" seen in skeletal material (Hawkey, 1998).

Another study that had a considerable impact upon the field was that carried out by Hawkey and Merbs, which examined patterns of enthesopathies in the upper limb in archaeological skeletal material from Thule Eskimos (Hawkey and Merbs, 1995). The skeletal material from the Thule Eskimos offered the opportunity to examine a relatively large, well preserved skeletal assemblage, which dates from a narrow time period and represents a culturally and genetically isolated population that is well reported historically. The study identified a right-dominant pattern of asymmetry in the pattern of enthesopathies in 80% of the individuals, a pattern similar to the proportion of right-handed individuals in modern populations. Sexual dimorphism in the patterns of severity and location of the entheses affected was also reported, and these findings were interpreted with reference to historical and archaeological information to suggest that females were predominantly involved in the preparation of skins, production of clothing and paddling boats, and the enthesopathies seen in males were also related to paddling kayaks (Hawkey and Merbs, 1995). Although the authors of this work related patterns of enthesopathies to specific activities particularly the use of boats, the archaeological evidence for the presence of boats at the sites in question was sparse, so the conclusions reached in this study should not be accepted without question.

The majority of studies of sexual dimorphism in enthesopathies in archaeological skeletal material have found lower levels of changes in females than in males, and related these differences to a sex-based division of labour (Eshed *et al.*, 2004, Steen and Lane, 1998, Wilczak, 1998), but there are some exceptions. A study of the prevalence and location of enthesopathies in the upper limb of human skeletons from Natufian and Middle Bronze Age Levant was carried out by Peterson (2000), with the aim of identifying sex differences in activity patterns in these prehistoric populations (Peterson, 2000). This study found that, in some of the Bronze Age sites, enthesopathies were more severe in females than males for some of the entheses examined, a finding that was supported by a parallel decrease in sexual dimorphism of the dimensions of the humerus, and lower levels of asymmetry in the appearance of enthesopathies in females. The unusual patterns of enthesopathies in females were interpreted as being the result of females undertaking a variety of farming activities including churning, grinding, milking, chopping, harvesting and tilling (Peterson, 2000). However, as was the case with the study by Dutour, clinical evidence to support these interpretations was not given, and, although Peterson mentions the need to control for age in enthesopathy studies, the age ranges of the skeletal samples were not given.

A study of the skeletal remains from the Mary Rose examined the presence of enthesopathies and robusticity in the skeletal material and noted the preponderance of changes to the humerus, clavicle, pelvis and femur (Stirland, 2000). Stirland concluded that these changes were the result of using large war bows, and the difficulties of standing upright on a swaying ship (Stirland, 2000). These conclusions are much more specific than those of most other studies of activity in skeletal populations; most researchers are very cautious of the extent to which they relate skeletal changes to specific physical activities, preferring to refer instead to general trends and differences between age and sex groups (Peterson, 2000). However, the Mary Rose crew are an unusual population in that a great deal is known about the types of people who were aboard the ship and the activities that they undertook. Most studies of MSM are undertaken because so little is known about the population in question and the conclusions must be more cautious.

An example of the more conservative nature of the conclusions drawn from studies of enthesopathies is that undertaken by al-Oumaoui et al (2004), where a total of five Spanish skeletal samples were examined to explore sex and population level difference in the patterns of enthesopathies (al-Oumaoui *et al.*, 2004). The samples included two prehistoric sites dating from the Copper Age (2800-2300 BC) and Bronze Age (1700-1200 BC), and three Medieval sites ranging in date from 850-1300 AD, which included a Muslim farming community, a Christian farming community who may also have been involved in warfare, and an agricultural population that served a small monastery. Enthesopathies were recorded in the upper and lower limbs, on the basis of presence or absence, and elderly and juvenile individuals were excluded from the samples under study. In all of the samples, the right upper limb had more enthesopathies than the left, but the degree of asymmetry varied between the sites. Patterns of sexual dimorphism in the upper and lower limbs were identified in all five skeletal samples, with males in all populations having higher frequencies of enthesopathies than females, particularly in the Muslim site where the culture required a clear division of labour between the sexes (al-Oumaoui *et al.*, 2004). This study also identified differences in the patterns of enthesopathies in the lower limbs between the sites, which correlated with the variations in terrain at the five sites, with frequencies of enthesopathies in the lower limbs being higher in the more mountainous sites (al-Oumaoui *et al.*, 2004). Although this work identified clear trends in the patterns of enthesopathies between the sexes and between the different sites, the authors did not try to relate these patterns to specific activities, and in their own words avoided "gratuitous speculation" (ibid pp 358), drawing instead upon the historical and archaeological information for each site to suggest broad patterns of activity which may have contributed to the variations seen (al-Oumaoui *et al.*, 2004).

As this brief review has demonstrated, there are many problems with the use of enthesopathies as MSM, so many that Stirland (1998, pp 360) suggested that "attempts to evaluate areas of muscle insertion, either by measurements or by subjective evaluation are doomed to failure" (Stirland, 1998). However, as more recent work has demonstrated, if the problems of subjectivity of recording, and the influence of age and sex upon the prevalence of enthesopathies are taken into account, it is possible to identify broad trends within and between populations. While enthesopathies may not be the "holy grail" of markers of specific activity and occupation that was once hoped for, research in this field has moved on from the search for "weaver's bottom" (Kennedy, 1989) and "kayaker's clavicle" (Hawkey and Merbs, 1995), and consequently it may still be possible to use these lesions as indicators of differences in levels of non-specific physical activity, particularly when the influences of age and sex are controlled (Weiss, 2003, Weiss, 2004).

1.3.5: Biomechanics and Asymmetry

As mentioned above, asymmetry in the presence of joint disease and enthesopathies in the limbs has been used to infer handedness and differences in limb use, but variations in the patterns of symmetry in the shape and size of bones, and the biomechanical properties of the long bones have also been used to infer differential patterns of use in archaeological material. One of the first studies of changes in bone morphology in archaeological material was that carried out by Pfeiffer (1980), which examined variability in the external size and shape of the humeri from a 17th century ossuary from Ontario, Canada (Pfeiffer, 1980). This study found that humeri from older adults were larger than those from younger individuals, and that the right sides were significantly larger than the bones from the left (Pfeiffer, 1980). While this study did not cite mechanical factors over the lifetime as a cause of the increase in humeral dimensions in older individuals, it does emphasise the need to control carefully for age when comparing bone measurements within and between samples. Other studies have been based on the premise that the human skeleton responds to mechanical stresses by increasing bone mineral density and remodelling to best adapt to changes in stress, a theory known as "Wolff's Law" (Pearson and Lieberman, 2004, Wolff, 1892). This stress then leads to changes to the bone dimensions and mechanical properties that can potentially be related to activity patterns (see Chapter 1.4.a for a more detailed discussion of this phenomenon).

As with osteoarthritis, variations in the morphology of long bones have been used to examine changes in subsistence strategies in archaeological samples. In addition to her research into patterns of osteoarthritis in hunter-gatherer populations from the South-Eastern U.S., Bridges also examined variations in long bone dimensions and cross-sectional properties (Bridges, 1989). This study identified an increase in the dimensions and strength of the long bones with the adoption of an agricultural economy, and variation in the limbs most affected amongst males and females. This was interpreted as representing sex related differences in the activities undertaken. In particular, the increases in dimensions seen in the left elbow in females were related to the method used for pounding corn (Bridges, 1989). Ruff *et al* (1984) compared structural characteristics of the femur in pre-agricultural and agricultural populations from Georgia, U.S., and identified a significant decline in the geometric properties of the bones in both sexes amongst the agricultural sample. This finding was taken as being indicative of a reduction in the mechanical load to the femur with the transition from a hunter-gathering economy to agriculture, although the possibility of a decrease in nutritional quality was also mentioned as a potential contributing factor (Ruff *et al.*, 1984).

A more recent study examined patterns of post-cranial robusticity amongst two groups of foragers with known differences in their patterns of mobility, to try to identify correlations between the skeletal material and the known activities of these groups (Stock and Pfeiffer, 2001). This work examined individuals from groups of Later Stone Age foragers from the south and east of South Africa, and individuals from the Andaman Islands in the Bay of Bengal, India, as, although these populations were spatially and temporally distant, they were of equivalent adult stature, culturally and technologically similar and lived in similar climates. This study found that, despite these similarities, there were significant differences in the patterns of long bone robusticity between the two groups, with the upper body long bones of the Andaman Islanders being more robust than the South African Later Stone Age samples, but this pattern was reversed for the lower limb (Stock and Pfeiffer, 2001). These variations were explained in terms of differences in subsistence strategy between these two groups, with the Late Stone Age foragers likely to have been more active on land than the Andaman Islanders, who made more use of marine resources and hence spent more time swimming or using boats. The more rugged landscape in South Africa may also have influenced the greater degree of robusticity in the lower limb seen amongst the Late Stone Age foragers (Stock and Pfeiffer, 2001).

Potential differences in activity levels between the sexes and between lay and monastic individuals from the 11th to 16th century sample from St Andrew, Fishergate, York, England, were examined using cross sectional analysis of the humerus (Mays, 1999). A sex difference in the degree of asymmetry in polar second moment of area in the humerus was noted between males and females, and interpreted as indicative of greater habitual loading of the upper limb in males than in females, possibly resulting from more long term involvement in crafts such as iron working, wood and stone working. There were few differences in the asymmetry of the polar second moment of area between the lay and monastic males, and it was suggested that the differences seen in the average measure of humeral strength might be due to genetic or nutritional differences between the two groups. However, it was also suggested that the variation seen might be due to the monastic males undertaking a lower level of manual labour than the lay males, a theory which is supported by the historical knowledge of life within a Gilbertine monastery (Mays, 1999).

In addition to being used to identify broad trends in activity, patterns of bilateral asymmetry and variations in cross-sectional morphology have also been used to identify specific activities in a variety of skeletal samples. High levels of asymmetry have been noted in the skeletal remains from Neanderthals (Trinkaus *et al.*, 1994), and one theory for the cause of this asymmetry is habitual use of spears (Schmitt *et al.*, 2003). When a large spear is held with two hands and thrust firmly, the forces upon the upper limbs are asymmetrical, and of sufficient magnitude to stimulate remodelling responses in the bones. Therefore, habitual use of spears for close range hunting may have been a cause of the right dominant asymmetry seen in Neanderthals and early modern humans (Schmitt *et al.*, 2003).

A number of studies have been carried out on the skeletal sample from the Medieval Battle of Towton, North Yorkshire, England, in AD 1461, which provides a unique opportunity to examine the skeletons from a group of professional soldiers who died on the battlefield. Amongst the men from Towton, only the maximum transverse diameter of the humeral head was significantly asymmetrical, with the right being larger than the left in all but one of the individuals, but overall there was no obvious right dominant asymmetry in this sample. The patterns of asymmetry observed from external measurements of the humeri were also seen in CT scans of humeral cross-sections (Knüsel, 2000). The variable degree of asymmetry in the humeri from Towton was interpreted as being the result of the predominant use of two-handed weaponry such as polearms and bows rather than single-handed weapons such as swords and war hammers

(Knüsel, 2000). More recently the cross-sectional morphology of the humeri from Towton has been compared with weapon injured and non-weapon injured males from Fishergate in York, dating from the 12th to the 16th century (Rhodes and Knüsel, 2005). This study found that there were significant differences in diaphyseal robusticity between the Towton sample and the comparative population from St Andrew Fishergate, and that the degree of asymmetry in diaphyseal shape was greatest in the Towton sample, suggesting that the patterns of loading and movement were different between the samples and between the sides within the Towton sample (Rhodes and Knüsel, 2005). The differences seen in diaphyseal shape between the two blade injured samples were interpreted as being a result of differences in their status as combatants. The Towton males appear to have been involved in activities which placed greater stresses on the left humerus, a finding that supports earlier research that suggested the use of two-handed weapons by these individuals, probably longbows. However, the Fishergate males with blade injuries had a pattern of robusticity that suggested a right-dominant pattern of activity, probably the use of a single-handed weapon such as a sword (Rhodes and Knüsel, 2005). As the Towton males were buried in a mass grave on the battlefield, the implication is that these were lower status individuals, and consequently were less likely to have access to swords, which were primarily used by higher status combatants.

Research similar to that undertaken on the Towton sample has also been carried out on the skeletal material from the Mary Rose, a sample which is often compared with Towton, as the remains are assumed to represent professional sailors, who were also involved in combat. A comparison of the paired humeri from the Mary Rose with a sample of males from Medieval Norwich found that the Mary Rose humeri were more symmetrical than those from Norwich, a pattern that was interpreted as being the result of the use of longbows by the sailors on the Mary Rose (Stirland, 1993, Stirland, 2000).

Despite the apparent value of analyses of asymmetry and biomechanics in examinations of patterns of physical activity in archaeological material, more recent work has cast doubts upon the value of these techniques. A comparison of the morphology of humeral cross-sections from a sample of 18th century prisoners of war from Quebec, Canada, who were reported to have undertaken heavy physical labour, with less physically active 20th century individuals from New Mexico, has recently been reported by Weiss (Weiss, 2005). This study found that the majority of robusticity measures examined and the pattern of asymmetry did not vary significantly between these two samples, despite differences in the patterns of injury, osteoarthritis and other pathological changes, and reported differences in the levels of activity undertaken (Weiss, 2005). The results of this study suggest that variations in bone morphology may not be related to activity levels, but may be more influenced by age, sex and nutritional factors.

1.3.6: Trauma

It could be argued that the changes seen in the enthesopathies, and to some extent the joints are the result of trauma, either repetitive micro-trauma or more severe traumatic events, but other specific forms of trauma have also been used as indicators of mechanical stress. Some forms of traumatic injury may be indicative of specific behaviours. Parry fractures, head injuries and weapon trauma may all be indications that the individual was involved in interpersonal violence (Bridges, 1996, Fiorato *et al.*, 2000, Owsley *et al.*, 1994), but whether these traumatic injuries or lesions should be used as indicators of habitual or occupational activity is open to debate. General patterns of injury within populations have been related to handedness, levels of physical activity, and environmental factors such as terrain (Grauer and Roberts, 1996, Kilgore *et al.*, 1997). Other specific forms of trauma have been associated with specific activities (Jurmain, 1999), some of which will be reviewed here.

The name "clay shoveller's fracture" highlights the occupational association of this form of trauma affecting the seventh cervical and/or first thoracic vertebra, which appears to be the result of overloading of the spinous process (Knüsel, 1996). The lesion has been seen in weightlifters, metalworkers and as the result of falls, motor vehicle accidents, and unsurprisingly, clay shovelling. While the cause of this lesion is relatively clear, unlike many other MSM, it is rarely seen and hence more likely to appear anecdotally than as a part of a population level study of patterns of activity related change.

Another lesion with a traumatic and congenital component in its aetiology, which is seen more frequently in archaeological material, is spondylolysis, a stress fracture of the *pars interarticularis*, most commonly seen in the lower thoracic and lumbar vertebrae. This lesion has been thoroughly reviewed by Merbs, and has been associated with the stresses of bipedalism, and activities including gymnastics, javelin throwing, weightlifting, and other sports (Merbs, 1996a). Merbs has examined the prevalence of spondylolysis in Inuit skeletal samples, and suggested that habitual activities amongst these individuals including wrestling, weightlifting, kayak paddling and using harpoons may have concentrated stresses upon the lower spine, leading to comparatively high frequencies of the lesion amongst the Inuit (Merbs, 1996b). A high frequency of spondylolysis was noted in a skeletal sample from Guam, and in this study the lesion was associated with harpoon fishing and production and transportation of heavy stones used in house construction (Arriaza, 1997).

More recently the prevalence of this lesion in British archaeological populations has been examined, identifying frequencies of between 12 and 15% of individuals affected, prevalence rates which are different to those reported in modern clinical studies, where 5 to 6% of European and American individuals are affected (Fibiger and Knüsel, 2005). This study also noted that, while the prevalence of this lesion was relatively low in British populations, Medieval populations were more affected than those from the early industrial period, and that this may have been due to differences in the levels of strenuous activity that these populations were exposed to (Fibiger and Knüsel, 2005). Although spondylolysis appears to be relatively sensitive to behaviour and mechanical stresses, identification of the lesion requires a good level of skeletal preservation, or the prevalence of the lesion may be underestimated. As this lesion is relatively uncommon in skeletal material from Britain, it may occur too infrequently for patterns within populations to be identified.

1.3.7: Multiple Indicators

There are many pathological and non-pathological skeletal changes that have been used as indicators of physical activity in archaeological material, but as has been discussed here and will be discussed further in Section 1.4, there are many problems with the validity of occupational and activity patterns interpreted from these changes. It is proposed that some of these problems may be overcome by examining patterns of occurrence of a combination of these potential markers. Where some conditions such as osteoarthritis and enthesopathy are associated with increasing age, other conditions such as Schmorl's nodes are less strongly correlated with increasing age, so patterns of Schmorl's nodes may act as a control to interpret patterns of other lesions. While enthesopathies and OA, and patterns of asymmetry may give an indication of the mechanical stresses affecting the limbs and appendicular joints, Schmorl's nodes will provide a picture of stresses acting upon the vertebral column.

Although there are at present no other studies that have examined osteoarthritis, enthesopathies, Schmorl's nodes and asymmetry in "ordinary" cemetery samples, other researchers have used more than one method to examine activity related stress in skeletal material. The work carried out on the Towton and Mary Rose samples, where patterns of OA, enthesopathies, asymmetry and biomechanical changes, non metric traits and vertebral OA and Schmorl's nodes have all been examined (Stirland, 2000; Knüsel, 2000), has already been mentioned here, but as both these samples are exclusively male, and do not represent "normal" populations, it is not possible to directly compare the findings of these studies with the present study.

However, one study of 14 skeletons from the Seafort Burial Site, Alberta, Canada (Lai and Lovell, 1992), examined patterns of osteoarthritis, enthesopathies, osteophytes, Schmorl's nodes and general robusticity of the skeleton and related these changes to specific activities that some of the individuals may have undertaken in life. Individuals buried at this site are likely to have been involved in the fur trade, and the patterns of changes seen in this sample were related to historically documented activities including rowing and carrying heavy boats, carrying large heavy packs and jogging over rough ground (Lai and Lovell, 1992). However, this study was not without problems; the sample size was very small, including only six adults and hence it was not possible to draw any conclusions regarding the statistical significance of the correlations between the conditions, or to exclude the possibility that the pattern of changes seen were the result of genetic, nutritional or ontological factors. A further study of four individuals from another fur trading site at Fort Edmonton in Canada followed the same pattern and reached similar conclusions, with the addition of dog sled driving and interpersonal violence as possible causes of some of the changes seen (Lovell and Dublenko, 1999). Again, the small sample size restricts the value of this study as a comparative site for other population studies.

Clearly, it is time for a large-scale examination of the relationship between a variety of conditions used as markers of activity related stress, and the socially stratified society of Early Medieval England should provide an opportunity to explore the relationships between social status and exposure to mechanical stress. As has been mentioned previously, an understanding of the aetiology of conditions used as musculoskeletal stress markers is vital to allow informed interpretations of patterns of these changes in archaeologically derived skeletal materials. The following chapter will provide a review of the clinical literature relating to the MSM that will be examined in this study: osteoarthritis, enthesopathies, Schmorl's nodes and asymmetry in the external dimensions of the humerus and femur.

1.4: Clinical and Archaeological Manifestations of Markers of Activity Related Stress

In this section clinical research into the conditions that were examined as markers of musculoskeletal stress in the present study, their probable causes and clinical manifestations will be reviewed. The methods used to identify these conditions in archaeological material will also be discussed.

1.4.1: Osteoarthritis

Osteoarthritis (OA) is one of the most common disorders in modern populations. In the United States, over 20 million people are thought to have the condition (NIAMS, 2000), and two studies carried out by the Arthritis Research Council (ARC) showed that in the year 2000, around 2.02 million adults in the UK consulted their GP with symptoms relating to OA and around 29% of adults say they are currently affected by arthritis or joint pain (ARC, 2002). Osteoarthritis and allied conditions incur a cost of around £5.5 billion per year to the health and social services in the UK (*ibid* pp 5), and in the year 1999-2000, 36 million working days were lost in Great Britain due to OA, representing a cost of £3.197 billion in lost production (*ibid* pp 9). The primary sufferers of the condition are the elderly, but people of working age can also be affected and, consequently, this has a significant economic impact as a result of lost working days (Sokoloff, 1969). Osteoarthritis and other joint diseases are clearly a common problem in modern society and, as the average age of populations increases, the social and economic problems caused by osteoarthritis are also increasing.

Many different conditions fall under the umbrella term of "osteoarthritis", although the term itself is somewhat misleading. The word "osteoarthritis" implies an inflammatory disorder of the bone and joints, while the condition is defined as "an inherently non-inflammatory disorder of movable joints characterised by deterioration and abrasion of articular cartilage, as well as by formation of new bone at the joint surfaces" (Hough and

Sokoloff, 1989, pp 1571). However, the relationship between these changes in the pathogenesis of osteoarthritis is not fully understood.

Osteoarthritis (OA) can occur in any of the synovial joints in the body, and degenerative changes can also be observed in some of the fibrous or semi fixed joints such as the sacroiliac joint and the medial clavicle. An understanding of the structure and function of synovial joints is important to the understanding of the development and progression of the condition. The synovial joints have evolved to protect the ends of the bones from damage, absorb shock and to allow smooth movement. Figure 1.4.1a shows the structure of a typical synovial joint.

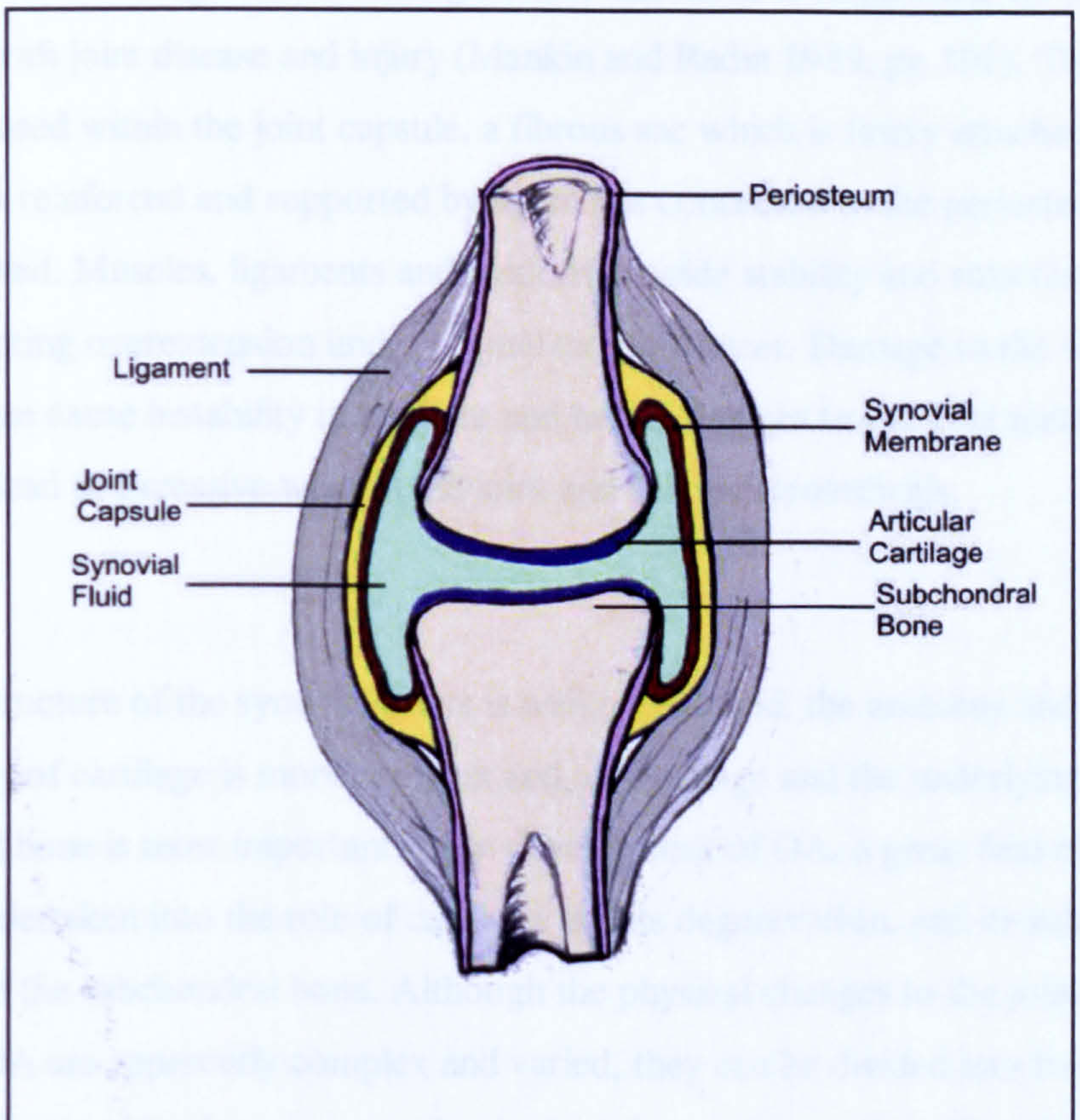


Figure 1.4.1a: The structure of a typical synovial joint, showing the articulating bones (beige), periosteum (pink), joint capsule (yellow), synovial membrane (red), articular cartilage (blue), synovial fluid in the joint space (turquoise) and the ligament supporting the joint (grey).

The terminal ends of the bones of the joint are covered with hyaline cartilage, a smooth layer of tissue, between 1 and 5 mm in thickness. Hyaline cartilage is composed of between 65 and 80% water, the fibrous protein collagen, proteoglycans, and chondrocites, the cells that produce cartilage. Under normal pressure the cartilage releases water into the joint capsule and cartilage can be compressed by up to 40% of its thickness (Jurmain, 1999, Mankin and Radin, 1989), allowing the joint surfaces to move against each other with very low friction. The articular cartilage has no nerves or blood vessels and is not connected to the lymphatic system; consequently the cartilage obtains nutrients from the synovial fluid. The internal surfaces of the joint capsule that are not covered with cartilage are lined with the synovial membrane, a vascular tissue that secretes synovial fluid, which serves as both a lubricant and nutrient for the cartilage. The synovial membrane has a good blood supply to provide nutrients to the cells producing synovial fluid, and it also has many nerve endings; together with the nerves in the joint capsule and surrounding muscles and ligaments, this tissue is responsible for the pain associated with joint disease and injury (Mankin and Radin 1989, pp 191). The whole joint is enclosed within the joint capsule, a fibrous sac which is firmly attached to the bones and is reinforced and supported by ligaments connected to the periosteum of the bones involved. Muscles, ligaments and tendons provide stability and structure to the joint, preventing overextension under normal circumstances. Damage to the surrounding structures can cause instability in the joint and hence changes to the joint mechanics which may lead to excessive wear in the joint and hence osteoarthritis.

While the structure of the synovial joints is well understood, the anatomy and biochemistry of cartilage is more complex and, as cartilage and the underlying subchondral bone is most important in the development of OA, a great deal of research has been undertaken into the role of cartilage and its degeneration, and its subsequent impact upon the subchondral bone. Although the physical changes to the joints that are caused by OA are apparently complex and varied, they can be divided into two categories; destructive changes occurring in the joint surface, and proliferative changes in the tissues adjacent to the joint surfaces. Osteoarthritis is essentially a disease of the articular cartilage which progresses to involve the subchondral bone of the joint, increasingly affecting the function of the joint (Mankin and Radin, 1989).

Some of the earliest stages of the development of the condition can be observed as changes in the biochemistry of the cartilage; healthy adult cartilage does not include collagen IIA, a variant of mature collagen type II which is formed in the development of cartilage, but collagen IIA is seen in joints with OA (Aigner *et al.*, 1999). In a study of transgenic mice, small mutations in type II collagen led to destructive joint diseases very similar to OA in humans. In these mice, the growth factor Sox9 and the structural matrix protein COMP (cartilage oligomeric matrix protein) were expressed in the earliest phases of joint change (Wollheim, 2003). The concentration of COMP in serum and synovial fluid is also an indication of disease progression in OA of the knee, as seen in radiographs over two years (Petersson *et al.*, 1998, Petersson *et al.*, 1997); it has also shown correlations with joint space narrowing in the hip (Conrozier *et al.*, 1998). Another change that is thought to be an early indicator of OA is an increase in the water content of the cartilage (hyperhydration), possibly as a result of changes to the collagen matrix (Jurmain 1999, pp 23).

As a result of hyperhydration, the cartilage of the affected joint surface becomes soft and begins to fray, referred to as fibrillation, giving it a velvety appearance (Hough and Sokoloff, 1989); this cartilage is abraded by the action of the joint, and as it cannot renew itself quickly enough, it becomes thin and, in some cases, completely worn away. It was initially thought that cartilage was incapable of repair, and that OA was primarily caused by the inability of damaged cartilage to repair itself, but adult articular cartilage has been shown to be capable of repair, albeit slowly (Radin *et al.*, 1972). Although these changes to the cartilage are often the earliest changes observed in the osteoarthritic joint, they may be preceded by changes to the adjacent bone (Hough, 2001). In regions where the cartilage is worn away the underlying bone of the joint surface can become stiffened (Mankin and Radin, 1989, McKinley and Bay, 2003), sclerotic and polished as a result of continuing wear. This ivory-like polishing is called eburnation and leaves the affected region of bone extremely smooth and shiny (Hough and Sokoloff, 1989) and in advanced cases can lead to scoring and ridging of the joint surface, particularly in the hinge joints such as the elbow (Rogers *et al.*, 1987). Subchondral cysts, (defects of the bone immediately beneath the joint surface) are a common feature of OA, particularly in the hip (Hough and Sokoloff, 1989), although there is no certainty regarding their cause or relationship with the other processes of the disease. It has been suggested that these cysts form as the result of intrusion of the synovial fluid into the subchondral bone, or that elevated pressure develops in the marrow, as the bone is not sufficiently strong to support the forces from the joint (Ondrouch, 1963). The increased pressure leads to a compromise in the blood supply, leading to the development of the cysts.

Adjacent to the joint surface, new bone and cartilage forms, possibly as an attempt to spread the load affecting the joint (Hough and Sokoloff, 1989) although in some cases this new bone formation impedes the movement of the joint and may lead to fusion (Sokoloff, 1969 pp 10). The new bone formation, or osteophytes, may encroach on to the joint surface, but is more commonly seen at the margins of the joint. Although the changes to the joint surface and joint margin most frequently occur together, it is possible to find cases where there is extensive eburnation but little or no osteophyte formation, and vice-versa.

i) Clinical Identification of Osteoarthritis

The primary symptom for the diagnosis of osteoarthritis (OA) in living patients is the presence of joint pain. This pain may be associated with stiffness and crepitus (creaking or crunching noises on movement) in the joint (Mankin *et al.*, 1986). Radiographically, other changes can be observed, such as marginal osteophytes, alteration in the shape of the articular surface, narrowing of the joint space, sclerosis of the subchondral bone and subchondral cysts. Using magnetic resonance scanning (MR), defects in the cartilage itself can also be identified (Boegard *et al.*, 1998). However, pain can be present in a joint without the presence of clinical signs of OA, and radiographic changes distinctive of OA, such as joint space narrowing and marginal osteophytes can be observed in joints without the presence of pain. Conversely individuals with total loss of cartilage cover resulting in eburnation of the joint may have no pain or limitation to the joint function (Rothschild, 1997 pp 531). Many studies have shown that there is often little correlation between the symptoms described by patients and the changes seen in radiological studies of joints;

one study showed that over 15% of radiological cases of OA were without symptoms (Jurmain 1999, pp 40).

In the grading system developed by Kellgren and Laurence in 1957, osteophytes were considered to be an early manifestation of OA, while narrowing of the joint space was considered to be a more advanced manifestation of the condition (Kellgren and Lawrence, 1957). However, more recent studies have challenged this understanding of the development of the pathological changes present in OA. Other studies of the knee joint have found a stronger association between joint pain and the presence of radiographically identified osteophytes than between pain and joint space narrowing (see Boegard et al, 1998 for references to some relatively modern studies). There is a strong correlation between the presence of radiographically diagnosed osteophytes in the tibio-femoral joint and cartilage defects identified by MR scanning in patients with joint pain; the occurrence of joint space narrowing is irrelevant in this study (Boegard *et al.*, 1998). Consequently, the presence of osteophytes alone cannot be used as a reliable indicator of OA in the living joint (Hough and Sokoloff, 1989).

ii) Aetiology and Epidemiology of Osteoarthritis

Osteoarthritis can be primary or idiopathic, and is generally thought to be the result of ageing and joint stress during the lifetime, or secondary to an abnormality of joint structure or as the consequence of a traumatic event that affects the stability and function of the joint (Moskowitz and Holderbaum, 2001). Primary joint disease tends to affect several joints in the individual, it is not so severe and is commonly seen in the elderly. Secondary osteoarthritis may be the result of congenital malformation or dislocation of the joint (Hough and Sokoloff, 1989), slipped epiphyses, metabolic or endocrine conditions, infection or infectious disease such as tuberculosis, trauma such as fractures, or conditions that lead to changes in the joint structure or function such as rickets (Moskowitz and Holderbaum, 2001). Essentially any condition that leads to alteration in the mechanical stresses upon a joint may cause secondary osteoarthritis. Consequently, secondary osteoarthritis tends to affect isolated joints, is often very severe and may be observed in younger individuals than primary osteoarthritis.

Osteoarthritis and Sex

Clinical studies have shown that females are more likely to develop OA (Radin *et al.*, 1972), and particularly poly-articular arthritis than males. The condition is more severe and symptomatic in women, and women are more likely to require total replacement of the hip (Birrell, 2004, Maillefert *et al.*, 2003). This apparent sex bias suggests that the sex hormones may have an influence in the development of OA, but whether this is a protective effect for males or a destructive effect upon females is uncertain. Interestingly, some studies have suggested that taking supplementary oestrogen afforded protection against OA of the hip and knee (Spector *et al.*, 1997, Vingard *et al.*, 1997), so the role that hormones play in the development of OA (if any) is clearly complex.

Genetic Factors

Studies of siblings and their spouses have shown that siblings are more likely to need a hip or knee replacement than spouses (Chitnavis *et al.*, 1997), indicating that there is a strong genetic component in the aetiology of OA. Relative to the control group of spouses, siblings were nearly twice as likely to need a hip replacement due to OA, and nearly five times as likely to need a knee replacement. In a study of hip involvement, siblings were between three and eight times more likely to have osteoarthritic changes than unrelated controls (Lanyon *et al.*, 2000).

Age

Age is clearly a factor in the development of OA (Radin *et al.*, 1972); the condition is seen most frequently in older people, but the exact cause of the connection between OA and ageing is still uncertain. It is possible that OA develops in older people as the result of wear and tear to the cartilage and joints over a lifetime of use, but it is also possible that it is the result of ageing of the tissues of the joint itself (Hough and Sokoloff, 1989, pp 1588). Stiffening of the subchondral bone, and incongruity of the joint surfaces may play a particularly important role in the development of OA in older individuals (Radin *et al.*, 1972). Osteoarthritis is rarely seen clinically in individuals under the age of 40 and, where younger individuals are affected, the condition is usually secondary to injury or disease (Moskowitz and Holderbaum, 2001).

Obesity

Overweight and obesity have been suggested as causative factors in the development of OA, particularly in the knee (especially in women) (Hough, 2001) and also in the hip (Moskowitz and Holderbaum, 2001). Obesity leads to larger thighs, which rub together and force a more bow-legged gait which, in turn, places extra stress upon the knees, and particularly the medial portion of the joint (Radin *et al.*, 1972). In a study of 1021 males and females, with ages ranging from 23 to 94 years who had been diagnosed with moderate to severe OA of either one or both hips, at least two-thirds of the sample were overweight. Although this study did not identify whether overweight and obesity were the cause of OA in these individuals, there was also no evidence that the presence of OA was the cause of the high body mass indices observed (Marks and Allegrante, 2002). The wear and tear to joints caused by weight bearing and movement has long been considered to be influential in the development of OA and, in individuals who are immobilized for long periods of time, contracture and ankylosis develop rather than OA (Hough, 2001). Case studies of single individuals have suggested that the presence or severity of OA is reduced in limbs with neurological defects, such as paralysis (Felson, 1994) and, in a study of patients with paralysis of one arm, the expression of OA was decreased in the involved hand, in comparison with the unaffected side (Segal *et al.*, 1998). However, other studies have demonstrated that, in joints where there is motion but no weight bearing, the cartilage is not normal (Hough, 1996), so there may be a mechanical role in both maintenance and degeneration within the joints.

Physical Activity

Physical activity and repetitive stress have been suggested as causative factors in the development of primary osteoarthritis but, while some studies have shown a correlation between physical activity and the prevalence of OA, other studies have found no connection (Shrier, 2004). The relationship between running and the development of OA is particularly unclear (Felson, 1994); in a Finnish study comparing champion runners with age and sex matched controls there was no increase in the frequency of OA in the hip in the runners (Puranen *et al.*, 1975), and several other studies have supported these findings (Moskowitz and Holderbaum, 2001). The Stanford study of OA in runners even showed that there was no increase in OA amongst runners, and that runners has lower levels of musculoskeletal disability than in controls (Lane *et al.*, 1987). These findings suggest that running may, to some extent, protect against the development of OA, rather than contribute to the development of the condition. However, in studies of former elite athletes including runners, tennis players and footballers, the prevalence of OA in the knee was higher than the rates seen in age matched non-athletes (Kujala *et al.*, 1995). Other studies have suggested that a general increase in non-occupational activity may be associated with an increased risk of OA of the hip (Moskowitz and Holderbaum, 2001). A further study showed that, while an increase in habitual physical activity lead to an increase in osteophytes in the knee, these were asymptomatic and did not constitute a increase in the severity of OA in the knee joint (Hannan *et al.*, 1993), so some manifestations of the condition may be more strongly associated with biomechanical factors than others. A flaw with many of these studies is the fact that they are retrospective, and do not take into account individuals who might have taken up a sport or activity, developed joint pain and stopped the activity. Hence, studies of individuals currently undertaking a sport or activity could be under-representative of the rates of OA, as only individuals capable of continuing the sport were examined.

Recently it has been suggested that wear and tear to the joints is not the most likely cause of exercise related OA, and that the level of exercise undertaken may be relevant to the risk of developing OA in the lower limb. The hypothesis that OA is the result of wear and tear to the joint assumes that impacts to the joints such as running should increase the prevalence of OA, and the severity of the condition in individuals who are already affected. However a review of the clinical evidence by Shrier (2004) did not support this hypothesis. Recreational involvement in running and soccer did not increase the risk of OA in the lower limb, but participation in sport at an elite level did increase the risk of OA, in both impact sports such as soccer and non-impact sports such as weightlifting (Shrier, 2004). The association between participation in sport at an elite level has been highlighted elsewhere, and the sports with the greatest risk of OA are those that inflict repetitive, high intensity and high impact forces upon the joints of the lower limb, and have the greatest risk of injury to the participants (Conaghan, 2002). Shrier (*ibid*) suggested that the increased risk of OA amongst elite athletes could be related to an increased risk of injury and a tendency to continue playing when injured, and that damage to the muscles, even at low levels, may be a more significant factor in the development of OA than general wear and tear. Muscle damage and fatigue can lead to instability of the joint and failure of the mechanisms for absorbing mechanical stresses, which then places the joint at a greater risk of degeneration (Shrier, 2004). It appears that muscular wear and tear and muscle fatigue may be significant factors in the development of OA, and this finding has implications for studies of the relationship between both exercise and occupational activity and OA. Where individuals are required to continue an activity when the muscles are tired or they have sustained even minor injuries, the risk of developing OA could be increased.

A variety of studies have been undertaken to examine the relationship between occupation and OA, and these generally fall into three categories; geographical studies that have compared regions where different types of subsistence activity prevail (e.g. urban vs. rural regions), studies of occupational groups (e.g. miners, weavers and farmers) to compare rates of the condition with controls, and studies of specific activities carried out by workers. Of the geographical studies, several have been carried out in Sweden. For example, a higher rate was observed in males from the Swedish island of Gotland, where farming is a major source of income, compared to that seen in the city of Malmo (Ingvarsson *et al.*, 1999). Similarly the rate of OA in Stockholm was lower than in more rural regions, and in Japan the urban population of Osaka had lower frequencies of OA than comparable rural populations (Moskowitz and Holderbaum, 2001).

As the geographical studies suggest that rates of OA are higher in farming communities than in urban regions, farmers have been a focus of studies of specific occupational groups. The evidence from these studies suggests that male farmers have a higher prevalence of OA than non-farmers, particularly in the hip (Moskowitz, 2001, pp 65 and Jurmain 1999, pp 88-90). There are several possible explanations for this association between farming and OA of the hip; firstly farming is generally a family occupation, and therefore the increased prevalence of hip OA in farming communities may be due to a genetic predisposition within farming families. Secondly, for the same reason, farm work is often begun at a relatively young age when the hip is not fully developed and vulnerable to increased physical stress. It is possible that the increased level of stress at a young age leads to trauma to the hip, which then causes OA later in life (Croft *et al.*, 1992). Croft et al (1992) suggested that bending, heavy lifting and walking over rough ground might be particularly implicated in the aetiology of OA in the hip in farmers, although no clear correlation with a specific activity could be established.

A high prevalence of the condition has also been observed in miners, and this occupation group had an earlier onset of degenerative changes in the hands, feet, spine, knees and hips than a control population (Anderson *et al.*, 1962, Kellgren and Lawrence, 1957). However, rates of OA in the hands of miners were not higher than those seen in manual workers (Felson, 1994) and there was no specific factor in mining that could be causally associated with OA in the knee (Lawrence, 1955). Pneumatic drill (jackhammer) operators have been shown to have high rates of prevalence of OA, and these workers also have OA in joints such as the elbow and wrist, which are not commonly affected in comparable individuals who do not use vibrating tools (Felson, 1994). However, other studies have produced contradictory results, suggesting that heavy lifting may be more of a factor in the development of OA in labourers rather than the use of heavy machinery (Jurmain 1999 pp 87-88). Specific types of lifting may also account for increased levels of severe OA observed in foundry workers, where their job involved lifting and working metal with long tongs. However, this group of workers also had lower levels of rheumatic disease than a random sample of the population (Felson, 1994).

A study of the hands of cotton mill workers carried out by Lawrence in 1961 identified higher rates of OA in the distal and proximal inter-phalangeal joints than the rates seen in the comparative groups of miners and housewives, as a result of repeated micro-trauma to the finger joints (Lawrence, 1961). A further study of female Virginian textile workers identified different patterns of radiologically and clinically identified OA in the hands and wrists of workers carrying out different tasks, suggesting that repetitive use and micro-trauma to a joint contributed to the development of OA (Hadler *et al.*, 1978). Although the correlation between specific activities and involvement of the hand in OA seems to be quite strong in mill and textile workers, other studies have produced conflicting results (Lane *et al.*, 1989, Waldron and Cox, 1989). It is likely that more systemic factors such as ageing and genetic pre-disposition play more substantial roles in the development of hand OA (Jurmain 1999, pp 86).

Overall, the evidence for a causative link between occupation and OA is conflicting; while some groups such as farmers seem to have strong correlations between occupation and increased levels of OA, many other studies have shown no correlation between occupation and OA. As mentioned above, there are problems with the samples that are used for studies of OA and occupation. In the majority of studies researchers examine individuals who are still involved in the activities in question, not taking into account the individuals who may have left the job. If former workers left the job as a result of musculo-skeletal conditions, this would lead to an under-representation of these conditions within the remaining workers. However, the apparently strong link between undertaking farming activities from a young age and the development of OA is probably the most relevant for studies of archaeological populations, as many of the tasks carried out by modern farmers have changed little from farming activities in the past. The activities that are suggested as the most influential in the development of OA in modern farmers, heavy lifting, bending and walking over rough ground were almost certainly undertaken by Early Medieval farmers to an equal or greater extent than modern farmers, although many other activities also require this range of movements.

Present and Past Rates of Osteoarthritis

It is difficult to fully assess the true prevalence of OA in modern populations as the condition can be present without causing symptoms, so would not be reported by all individuals affected (Cobb *et al.*, 1957). By the age of 40, 90% of all individuals have degenerative changes in the weight bearing joints, but generally clinical symptoms are absent (Moskowitz and Holderbaum, 2001). This may lead to problems in comparing prevalences between modern and archaeological populations; the frequency of occurrence in archaeological skeletal material may be greater than that reported in modern populations, as the frequency in modern populations may be artificially small. Furthermore, the criteria used to identify OA, such as symptoms, radiological or MRI appearance, or self-reporting by patients, varies widely between studies, making it difficult to compare prevalence rates of the condition between studies (Ingvarsson *et al.*, 1999).

iii) Archaeological identification of Osteoarthritis

Identification of OA in an archaeological context is not a simple process. Although the signs of the disease are easy to observe in living individuals, some of the changes to dry bone that are due to OA are similar to changes caused by other joint diseases and taphonomic processes. Rogers et al (1987) stated that, in skeletal material, OA is characterised by marginal osteophytes, subchondral bone reaction (e.g. eburnation, sclerosis and cysts), pitting of the joint surfaces and in some cases alterations in the joint contours, and that in the absence of osteophytes and subchondral bone reaction, OA should not be diagnosed (Rogers *et al.*, 1987). Clearly, the most certain sign of OA in skeletal material is eburnation; this change is only caused by joint degeneration resulting from the total loss of cartilage cover (Rothschild, 1997), is very easy to identify and can be observed even when the joint surface is fragmented. It has been suggested that OA in archaeological material should only be recorded where eburnation is present (Rogers and Waldron, 1995). This, however, may artificially reduce the prevalence of the condition in archaeological populations as, in a clinical context, not all cases of the disease progress to eburnation. It has also been argued that eburnation should be used as an indicator of the severity of OA rather than solely as evidence of the presence of the condition (Rothschild, 1997). Sclerosis of the subchondral bone and subchondral cysts are signs of the condition in living patients but can be difficult to observe in dry bone without a radiograph of the joint surface in question. Pitting or porosity of the joint surface may be related to arthritic change in the joint, but can be difficult to differentiate from damage to the joint surface resulting from taphonomic processes. The presence of osteophytes at the joint margin and on the joint surface has been used as an identifying characteristic, although OA is not the sole condition to cause these changes, and hence osteophytes alone should not be used to diagnose OA.

As mentioned above, the clinical diagnosis of OA is primarily based upon the presence of pain, osteophytes and joint space narrowing. Of these three factors, the only one visible in skeletal material is the presence of osteophytes and, when these are observed in skeletal material it is important to differentiate between osteophytes at the joint margin, and osteophytes which may have formed at peri-articular entheses, or inflammation of the periosteum (Rogers *et al.*, 1987), as the aetiology of these may be different from those at the joint margin. To some extent, narrowing of the joint space may be observable in archaeological material when remodelling of the joint contours has occurred but, as joints are frequently incomplete, it is not always possible to accurately "reconstruct" a joint. Furthermore, as the cartilage is not present in archaeological material, it is virtually impossible to be sure of the appearance of the joint space.

The other joint changes used by palaeopathologists to identify OA in dry bone, such as eburnation are seldom visible in living patients unless the joint is examined surgically, or replaced; consequently, they are rarely mentioned in the clinical literature as methods for identifying the condition. Porosity is seen in the articular surfaces of dry bone, but is not identified as a clinical change associated with OA, and it is not visible in radiographs (Rothschild, 1997). Explanations for the presence of porosity in dry bone include the intrusion of synovial fluid into the subchondral bone through cartilage defects (Sokoloff, 1969), or exposure of the marrow spaces as a result of the wearing away of the subchondral bone denuded of cartilage (Merbs, 1983). As the cause of porosity and the relationship of this change is not fully understood, porosity alone should not be considered as being indicative of the presence of OA in archaeological material (Rothschild, 1997).

In the light of these difficulties it is clear that a conservative approach to diagnosing OA in archaeological material should be taken. The widely used recording text *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994) defines the typical features of OA as seen in archaeological remains as "*lipping* (bony spur or osteophytic development) marginal to the articular surface, *porosity* of the surface, and *eburnation*" (Buikstra and Uberlaker 1994, pp 122). The extent to which the joint is affected by these features and the severity of each feature is then recorded. Although this system is relatively simple to use, it is by no means perfect; photographs of joints affected by osteophytes, porosity and eburnation are given, but each different grade is not shown, leaving a great deal to the imagination of the observer and increasing the risk for inter-observer error.

Taphonomic processes can have a major influence on the diagnosis of OA in archaeological material. If a bone or skeleton is incomplete it is possible that factors such as trauma, malformation of the limb or joint, or the presence of other conditions that could pre-dispose the individual to OA may not be identified. Poor preservation may also lead to incomplete joints, reducing the opportunities for identifying pathological changes, and incompleteness of the skeleton can lead to misdiagnosis of specific joint disease as the pattern of joints affected is often distinctive of a particular arthropathy (Rogers *et al.*, 1987).

1.4.2: Enthesopathy

The entheses are the transition zones between bones and the muscles, tendons, ligaments and joint capsules. Enthesopathies (also known as enthesophytes and syndemoses) are regions of bony change, usually rough patches of bone growth or periostitis at the entheses. New bone growth takes place as part of the process of healing at the enthesis, following trauma or inflammation (Freemont, 2002). The more general term of "tendinitis" is also used in some of the clinical literature to refer to pathologies that involve the entheses. There are issues with the terminology used to describe these lesions; the term "enthesopathy" refers specifically to a pathological enthesis, the "-pathy" suffix denoting disease (pp 490, Oxford Concise Medical Dictionary, 5th Edition, 2000), and is has been suggested that "enthesophyte" is a more suitable term for these lesions, as this refers to the observed bony change, rather than the pathological interpretation (C. Knüsel, *pers comm*). However, as will be discussed below, the manifestation of these changes in human skeletal material is not restricted to bone formation at the entheses, as indicated by the term enthesophyte; cortical defects can be present, either in isolation or in association with new bone formation. Therefore, throughout this thesis the term "enthesopathy" will be used to refer to any change identified at the entheses, as this is the most widely used term in both the clinical and archaeological literature and does not imply one form of change over the other.

Entheses can be divided into two types according to their structure and location; they can be either fibrous or fibrocartilaginous. Fibrous entheses are those that attach the tendons and ligaments to the metaphyses and diaphyses of long bones, while fibrocartilaginous entheses are those seen in the apophyses and epiphyses of the long bones, the short bones of the hands and feet and in some of the ligaments of the vertebral column (Benjamin and McGonagle, 2001).

In the fibrous entheses, the tendons and ligaments are attached to the bone or the periosteum by compact fibrous connective tissue. The involvement of the fibrous entheses in disease is thought to be limited (Claudepierre and Voisin, 2005), although this may be an artefact of a clinical bias towards study of the fibrocartilaginous entheses (Benjamin *et al.*, 2002). In the fibrocartilaginous entheses both fibrocartilage cells and matrix are present at the site of attachment, and the enthesis consists of four distinct zones (Benjamin and McGonagle, 2001, Claudepierre and Voisin, 2005). The first of these zones is the end of the tendon or ligament, which gradually changes into the second zone- unmineralized fibrocartilage. The third zone is mineralised fibrocartilage, with the transition between the second and third zones being marked by a mineralization front, sometimes referred to as the tidemark, while the fourth zone is the trabecular bone (Benjamin and McGonagle, 2001, Claudepierre and Voisin, 2005). The periosteum, the membrane that covers bone, into which the entheses insert, is very well supplied with capillaries, which provide nutrition to the entheses. As stresses such as the pull of a muscle occur, the number of capillaries increases; this increase in blood flow leads to a localised build-up of bone by osteons, resulting in hypertrophy of the insertion site (Peterson, 2000). Entheses are also richly innervated, and consequently much of the pain felt by patients suffering from spondyloarthropathies and other rheumatic conditions may originate from problems at the entheses (Benjamin and McGonagle, 2001).

The function of the entheses is to distribute the forces associated with movement over a broad area of the bone surface, to absorb impacts to the musculoskeletal system (Claudepierre and Voisin, 2005) and to dissipate stress away from the tendon/bone interface and into the bone itself (Benjamin *et al.*, 2002). Fibrocartilage in the entheses is thought to have a role in the dissipation of bending stresses away from the bone, and it has been suggested that fibrocartilage responds to mechanical load and hence the quantity of the tissue might vary according to activity levels (Benjamin and McGonagle, 2001). This fibrocartilage can become calcified, and when this occurs the resulting bone survives well in macerated specimens (Haines and Mohuiddin, 1968). Some ligament and muscle insertions also show erosive lesions, where the destruction of bone has outstripped formation during remodelling (Hoyte and Enlow, 1966); this is particularly the case in ankylosing spondylitis (Rogers and Waldron, 1989) and in other inflammatory enthesopathies (Freemont, 2002). These lesions form when the bone and cartilage are destroyed, and in living tissue these lesions are rapidly re-filled with woven bone, and subsequently lamellar bone (Fournie, 2004). It is therefore possible that the lytic defects seen in archaeological skeletal material represent early phases of enthesopathies, or cases where the stress to the enthesis has continued and prevented repair. Bone formation at the entheses is most common at the Achilles and patellar tendons, the plantar aponeurosis and the coraco-acromial and spinal ligaments, and the iliac crest (Benjamin and McGonagle, 2001, Freemont, 2002).

i) Clinical Identification of Enthesopathies

Although analysis of enthesopathies in an archaeological context has become increasingly popular in recent times, until recently little clinical information about these phenomena was available. In the past few years more investigations into the aetiology of these changes have been carried out. However, studies of the prevalence of enthesopathies in modern populations are still few and far between; this is probably because in the majority of individuals, enthesopathies are painless and cause few problems with function of the muscle and bone involved. The few clinical studies of enthesopathy that have been carried out tend to relate to elite athletes and individuals who are involved in tennis, running and baseball pitching.

The major exception in the clinical data is in relation to conditions where enthesopathy is a factor such as diffuse idiopathic skeletal hyperostosis (DISH), and spondyloarthropathies such as ankylosing spondylitis, psoriasis and Reiter's disease. In the case of these conditions, the changes to the entheses are inflammatory (Rogers and Waldron, 1989). Inflammation at the entheses is commonly seen at the Achilles tendon and plantar fascia in patients with spondyloarthropathies, and has also been identified in the synovial joints of patients with these conditions (Benjamin and McGonagle, 2001). In the spondyloarthropathies, infection of the entheses had been implicated as a cause of this inflammation in some cases (Freemont, 2002), and diabetics may also be at increased risk of developing these lesions, although some studies have produced conflicting results (Claudepierre and Voisin, 2005). In the spondyloarthropathies initial manifestation of the enthesopathy is pain in the affected region, an increased uptake of radionucleotides and changes to the enthesis, which are visible with magnetic resonance imaging (MRI) or ultrasound scans. These changes are followed by radiographic changes such as sclerosis and osteolysis, hyperostosis leading to bone spurs, and in some cases ankylosis (Fournie, 2004).

ii) The Aetiology and Epidemiology of Enthesopathies

The aetiology of enthesopathies is not fully understood, but they are variously thought to be the result of physical stresses, sudden or repetitive trauma (Freemont, 2002), diet, inflammation, metabolic and endocrine disorders, fluorosis, aging or the result of bone forming diseases such as diffuse idiopathic skeletal hyperostosis (DISH) (Aufderheide and Rodrigues-Martin, 1998, Benjamin and McGonagle, 2001, Jurmain, 1999, Resnick and Niwayama, 1983). It has been suggested that some individuals may be "bone formers", with a predisposition towards developing enthesopathies, but not necessarily displaying the signs of "full-blown" DISH (Rogers *et al.*, 1997). If this is the case, these "bone formers" present a problem to the researcher interested in using enthesopathies as indicators of physical activity. If it is not possible to distinguish these individuals from those who have undergone heavy or repetitive physical activity, they cannot be excluded from a study. This problem highlights the value of studies using multiple indicators of activity; if enthesopathies are seen in association with another change, it is more likely that they are the result of activity. It is also important to examine the whole skeleton for changes; if enthesopathies are seen all over the body, it is more likely that the individual is a "bone former" than if they are restricted to a particular region or side of the body.

Sex and Enthesopathies

There is evidence, primarily from studies of archaeological material, that the frequency and size or robusticity of enthesopathies is greater in males than in females (Wilczak, 1998), possibly as a result of hormonal influence, but most likely as a consequence of the fact that the bones and muscles of males are usually larger and more robust than females (Benjamin *et al.*, 2002, Weiss, 2003, Weiss, 2004). There is a strong association between the incidence of DISH and sex, with males twice as likely to have the condition than females (Mazieres and Rovensky, 2000). However, as no clinical research has been carried out into the influence of sex upon the development and severity of enthesopathies where DISH is not a factor, the findings of archaeological studies should be treated with caution, particularly where sex differences in the patterns of enthesopathies are then used to try to reconstruct sex differences in patterns of activity.

Age and Enthesopathies

Ageing is also thought to play a role in the development of enthesopathies, and is associated with an increased prevalence of asymptomatic enthesopathy as seen in radiographs (Claudepierre and Voisin, 2005). In the Hamann-Todd skeletal collection, derived from autopsies, the presence of enthesopathies increased with age in individuals who did not have clinical signs of other arthritic conditions (Shaibani *et al.*, 1993). However, it has been suggested that the development of the entheses might lead to a greater risk of injury to the entheses in the young. During childhood, the tendon in fibrous entheses is attached to the periosteum, rather than the bone as is the case in adults, but in the fibrocartilaginous entheses the transitional zone is present throughout life (Benjamin and Ralphs, 1996). Therefore, it is possible that the fibrous entheses are more vulnerable during the period of growth than the fibrocartilaginous entheses and, as a result, it may be possible to identify differences in the location of enthesopathies in younger and older adults. As a consequence of the uncertain relationship between age and the development of enthesopathies, studies of the prevalence of enthesopathy in both modern and archaeological populations need to be controlled for age.

Physical Activity

Mechanical factors are thought to play a significant role in the aetiology of bone formation at the entheses, hence the utilisation of these changes as evidence of musculoskeletal stress. Heavy experimental loading of entheses in the rabbit knee lead to tendon evulsions and micro-trauma in the entheses and in the subchondral bone (Claudepierre and Voisin, 2005). Additionally, cyclical loading of the forelimb in rabbits led to significantly greater levels of damage to the tendon and enthesis of the flexor digitorum profundis on the side subjected to loading (Nakama *et al.*, 2005). This research shows that micro-trauma resulting from repetitive stress to the muscles, tendons and ligaments, may be instrumental in the development of enthesopathies. Inactivity also affects the health of the entheses; the immobilization of the quadriceps in rats led to regression of the fibrocartilaginous zones (Claudepierre and Voisin, 2005), and immobilization of the knees of monkeys with casts over eight weeks led to a weakening at the entheses of the anterior cruciate ligament (Benjamin and Ralphs, 1996).

The prevalence of enthesopathies is greater in the lower limb, and it is likely that this is due to the greater mechanical stresses that are placed upon the lower limb than the upper limb (Benjamin and McGonagle, 2001). The mechanical stresses on the plantar fascia and Achilles tendon are particularly great, and these are the regions that are most frequently affected in the spondyloarthropathies (ibid pp 522). However, patients with tetra or paraplegia have also developed enthesopathies, suggesting that physical stress or weight bearing is not the only cause of this condition (Niepel and Sit' Aj, 1979) and that immobilization alone does not either prevent or cause enthesopathy. Some degree of movement or weight bearing is clearly important for the well being of the entheses and, consequently, it is likely that to some extent, enthesopathies are a part of the normal anatomy of the musculoskeletal system, and may be illustrative of patterns of physical stress.

Sporting activities and other repetitive physical activities are the most frequent cause of symptomatic enthesopathies in otherwise healthy individuals (Claudepierre and Voisin, 2005), and a variety of activity specific forms of enthesopathy have been identified, including golfer's elbow (medial) and tennis elbow (lateral epicondylitis), jumper's knee and Osgood-Schlatter's disease (Benjamin and McGonagle, 2001). Tennis elbow, affecting the tendons of the lateral epicondyle, is the best-known non-inflammatory enthesopathy, and is most common in the dominant arm of individuals ranging from 30-55 years of age (Benjamin and Ralphs, 1996). The name "tennis elbow" is somewhat misleading; most patients with tennis elbow have a history of repetitive overuse of the forearm, but not necessarily from playing tennis, and the condition is likely to be the result of any exercise or occupation that requires forcible extension of the wrist, or pronation and supination (Pinals, 1989). Around 15% of patients with tennis elbow also have other tendon pathologies in the upper arm (Benjamin and Ralphs, 1996), and it is possible that this reflects an underlying factor that predisposes some individuals towards enthesopathies. Many of the cases of rheumatic disease in the elbow amongst workers using pneumatic drills that were initially reported as "osteoarthritis" may in fact have been enthesopathies, particularly the formation of bone spurs on the olecranon (Felson, 1994), and other studies have also reported high frequencies of olecranon spurs in mechanical drill operators (Jurmain 1999, pp 160).

Bony spurs at the entheses are commonly observed in athletes, and the formation of these spurs has been equated with the development of the tubercles and tuberosities present on many of the bones (Benjamin and McGonagle, 2001). These tuberosities are formed as the result of muscle action upon the bone, and have been induced experimentally (Claudepierre and Voisin, 2005). Consequently, it is likely that bony spurs at the entheses (also referred to as "traction spurs", Freemont, 2002 pp 4) are also the result of mechanical stress. Other less dramatic changes to the entheses may also be associated with activity; mild periostitis of the attachments of the soleal muscle may be related to stresses on the Achilles tendon resulting from pronation of the heel in walking and running (Michael and Holder, 1985). Most frequently quoted in archaeological studies of enthesopathies are the studies of baseball pitchers, where osteophytes have been observed in the elbows of young players (Adams, 1976) and in 44 % of professional players (King *et al.*, 1969), as a result of the supination and hyperextension of the arm required in baseball pitching. It would be interesting to examine the elbows of professional cricket players to see if they are affected in the same way.

Jumper's knee, another painful enthesopathy that affects the attachment of the patellar tendon to the lower pole of the patella is commonly seen in players of volleyball and basketball. It is thought to be associated with sudden increases in the intensity of training, or training on hard surfaces (Benjamin *et al.*, 2002). In patients with this condition the lower pole of the patella is often more pointed than normal, perhaps as a result of the deposition of new bone at the enthesis. Osteophyte formation in the ankle has been shown to be more common in university athletes than in controls, and high prevalences are also seen in dancers, footballers and American football players (Jurmain, 1999). However, ankle injuries are extremely common, accounting for around 25% of all musculoskeletal injuries (van Dijk, 2002), so it is not surprising that high levels of ankle involvement are seen in athletes.

Environmental Factors

The environment can also influence the epidemiology of enthesopathies and other musculo-skeletal injuries. The scientific research station on the sub-Antarctic Macquarie Island is notorious for high rates of knee and ankle injuries, particularly enthesopathies of the quadriceps tendon, and it is likely that this is due to the rocky terrain and poor weather conditions on this island, where walking is the main mode of transport (McGaughey and Sullivan, 2003). While patella tendinitis ("jumpers knee") is more commonly seen in the general population than enthesopathy of the quadriceps tendon, amongst the expeditioners of Macquarie Island this pattern was reversed, probably due to the nature of the uneven, steep and icy terrain, prohibiting running and jumping (causes of patella tendinitis) and encouraging repeated ascents and descents of steep slopes (a possible cause of damage to the quadriceps tendon) (McGaughey and Sullivan, 2003). Furthermore, the individuals who were most affected by enthesopathies of the quadriceps were those members of expeditions who did not regularly walk around the island, suggesting that infrequent exposure to difficult walking conditions was more likely to lead to injury than in the individuals who undertook strenuous walking on daily basis.

As many enthesopathies are asymptomatic and frequently difficult to identify radiographically (Jurmain, 1999), clinical studies of the relationships between activity, occupation and the frequency of enthesopathies are not as common as those examining OA and activity. There are many studies of tendinopathies or tendinitis and the impact of physical activity and sport upon the health of the tendons (Murrell, 2002) but, as tendinopathies do not necessarily lead to osteophytes or enthesopathies, it is not feasible to relate the findings of these studies to the patterns of enthesopathies in archaeological material. At present the aetiology of enthesopathies is not well understood, which leads to problems of interpretation of these changes in an archaeological context (Jurmain, 1999).

iii) Archaeological Identification of Enthesopathies

Although enthesopathies are easy to observe in archaeological material (Rogers and Waldron, 1989), appearance of enthesopathies in archaeological material can be very varied, ranging from regions of woven or lamellar bone deposition to crests or spicules of bone at the entheses; the bone formation can be smooth or irregular, but usually has well defined margins (Resnick and Niwayama, 1983). Enthesopathies can also manifest as lytic defects in the cortical bone, also referred to as "stress lesions" (Weiss, 2003, Weiss, 2004). Furthermore, bone deposition and bone removal can occur together (Hoyte and Enlow, 1966), resulting in more than one type of change being present at a single enthesis. The appearance of enthesopathies can also vary according to the specific enthesis concerned; for example, the costo-clavicular insertion site on the clavicle is very different in appearance to the greater trochanter of the femur, but enthesopathies can be observed at both of these locations. As a result of this variation in appearance, the definitions of enthesopathies at different sites in the skeleton vary from study to study, and there are problems in the attribution of scales of severity to these different types of enthesopathy. The system developed by Hawkey and reported in Hawkey and Merbs (1995), attempts to address this issue, and scores lytic defects in the bone cortex separately from "robusticity", rugged bone formation such as crests and ridges at the entheses, and "ossification exotosis" or bone spurring, thought to result from abrupt muscular trauma (Hawkey and Merbs, 1995). This system records cortical defects as being more severe than "robusticity" (Hawkey and Merbs 1995, pp 329), but there is no evidence from the clinical literature that these first lesions are more severe or the result of greater stress to the enthesis than bone formation or robusticity.

The study of enthesopathies in an archaeological context is hindered by two major problems; firstly that there is no widely accepted set of standards for identifying and recording enthesopathies, and secondly that many of the earlier studies were anecdotal and made assumptions that were not soundly based upon clinical research (Kennedy, 1998). Circular arguments are rife in this field; it was assumed in the earlier studies of patterns of enthesopathies (particularly the study reported by Dutour in 1989) that the changes seen in archaeological skeletal material were the result of an occupational or habitual activity, and there was no reference to clinical studies of the relationship between specific activities and enthesopathies to support the findings (Jurmain, 1999). As has been discussed above, few clinical studies of specific activity and the epidemiology of enthesopathy exist. Consequently, archaeological studies of the relationship between activity and enthesopathy tend to rely upon the results of other archaeological studies to "validate" their conclusions. Until more large-scale epidemiological studies of enthesopathies in living populations (or skeletal samples with detailed and reliable history) are carried out, preferably with reference not only to patterns of activity within the sample population but to other factors such as injury, diet, genetic factors and other medical conditions, osteologists must be cautious in the conclusions that they draw from patterns of enthesopathies.

The dearth of clinical information about the appearance of entheses and enthesopathies in living individuals also makes it difficult for osteologists to identify the "normal" range of changes as seen in archaeological bone. As we are not certain what level of change is within the normal range, it is possible that the prevalence of enthesopathies in archaeological samples is artificially high or low when compared to prevalence rates in clinical studies. As mechanical factors are not the only cause of enthesopathies, in skeletal material it is important to try to differentiate between enthesopathies which may be the result of mechanical factors and those that are due to other factors such as ageing, trauma, disease, diet and other systemic factors. In the majority of archaeological skeletal samples it is virtually impossible to exclude the possibility that enthesopathies are the result of genetic or dietary factors without further scientific testing, such as DNA tests or examination of dietary isotopes. However, it is possible to control for age and, to some extent, trauma and disease. By examining the patterns of change across the whole skeleton it is possible to identify cases of trauma and exclude individuals where the development of enthesopathies may have resulted from such trauma. Likewise, examination of the vertebral column, together with the appendicular skeleton, allows obvious cases of diffuse idiopathic skeletal hyperostosis, (DISH) and other seronegative spondyloarthropathies such as ankylosing spondylitis and Reiter's disease to be identified. However, when the skeleton is incomplete, both trauma and severe DISH cannot be fully excluded as factors. Although DISH is identified clinically by the fusion of at least three contiguous vertebrae, extra-spinal manifestations of the condition can be present with only very minor changes to the vertebral column (Rogers *et al.*, 1987). In living patients DISH may in some cases be diagnosed even when there are no visible spinal changes by the presence of calcaneal, olecranon or patella spurring, ossification of the entheses, pain and stiffness in adults over 50 and palpable spurs around the patella, elbow or heel (Mazieres and Rovensky, 2000). Therefore, it is possible that some of the cases of enthesopathies seen in archaeological material, particularly in individuals where multiple entheses and limbs are involved, may in fact be early cases of DISH. The problems of accurate diagnosis emphasise the need to take a population perspective of this potential marker of musculoskeletal stress to examine trends in the levels of changes within and between populations rather than to attempt to ascribe specific patterns of activity to individuals on an anecdotal basis.

1.4.3: Schmorl's Nodes

Back pain affects between 60 and 80% of the modern population at some time during life, and in between five and ten percent of cases it is chronic or recurrent (Urban and Roberts, 2003), leading to a cost of £1632 million to the health service in the UK (Fairbank, 2002). Although back pain can be the result of many factors, degeneration and herniation of the intervertebral discs is implicated in many cases of severe or chronic back pain (Fairbank, 2002, Rannou *et al.*, 2003).

Schmorl's nodes are a form of lesion that develops as the result of the herniation of tissue from the intervertebral disc into the surface of the vertebral body (Schmorl and Junghanns, 1971). Schmorl's nodes take the form of a depression or fossa in the vertebral surface, usually with smooth, rounded edges and most frequently in the centre of the surface, or toward the posterior of the vertebral surface. These lesions can be found on both the inferior or superior surfaces of the vertebrae and in any region of the vertebral column, but there is anecdotal evidence that Schmorl's nodes are more frequent in the inferior vertebral surface, and the thoracic region of the vertebral column (Resnick and Niwayama, 1978, Saluja *et al.*, 1986). As Schmorl's nodes are caused by the herniation of the intervertebral disc, an understanding of the biology of the intervertebral disc is required to understand the aetiology of these lesions.

As the name suggests, the intervertebral discs are located between the vertebral bodies and act as a means of transmitting loads through the spinal column, providing flexibility and acting as major joints in the vertebral column (Schmorl and Junghanns, 1971). The intervertebral disc is "a cartilaginous structure that resembles articular cartilage in its biochemistry, but morphologically it is clearly different" (Urban and Roberts, 2003, pp 120). The disc is composed of the annulus fibrosus, a thick outer ring of fibrous cartilage, surrounding the nucleus pulposus, an inner core of radially arranged collagen and elastin fibres within a matrix of highly hydrated cartilage gel. The water content in the nucleus pulposus is extremely high, ranging from 88% in neonates to 70% in a 72-year-old adult (Schmorl and Junghanns, 1971). Above and below the nucleus pulposus are hyaline cartilage end plates, which interface between the disc and the vertebral body (Urban and Roberts, 2003). In adults the intervertebral disc is usually avascular but does have some nerves, while the cartilaginous end plate is avascular and aneural. Cells constitute only 1% of the disc by volume, but these cells play an important role in tissue turnover within the intervertebral disc as they are responsible both for breaking down and repair of the matrix (Bibby *et al.*, 2001). The junction between the disc and the vertebral surface is similar to a synovial joint in that, in both structures, hyaline cartilage is present at the bone surfaces, the annulus fibrosus is similar to the joint capsule and the nucleus pulposus is similar functionally to synovial fluid (Peng *et al.*, 2003). These similarities are due to the function which the intervertebral disc plays in the vertebral column.

The spine is the central motor organ of the body, and the intervertebral discs and their role in the "motor segments" of the spine facilitate a large proportion of this motor function. The motor segments of the spine consist of an intervertebral disc, the vertebral surfaces superior and inferior to the disc and the apophyseal joints of these vertebrae. Within the motor segment, the disc acts as a shock absorber and permits torsion of the spine, and the concentric rings of fibrocartilage in the annulus fibrosus help to counteract shearing forces inflicted upon the spine (Schmorl and Junghanns, 1971).

According to Schmorl and Junghanns, herniation of the disc into the adjacent vertebral body can only occur when gaps in the cartilaginous end plates are present (Schmorl, G and Junghanns, H. 1971, pp 158), and some of the possible causes of these regions of weakness will be discussed in section 1.4.3 ii. The herniation of disc tissue through these weak areas leads to pressure on the trabecular bone of the vertebral surface, which in turn causes resorption of the bone, creating a small cavity which is filled by the herniated disc tissue. The pressure of the disc tissue leads to the development of a cartilaginous lining to the cavity in the vertebral surface, which over time, becomes ossified (Schmorl and Junghanns, 1971). It is these ossified cavities which are observed in archaeological skeletal material. Schmorl's nodes can be rounded or elongated in form and can occur on any part of the vertebral surface except the vertebral rim, but are most commonly seen in the region of the nucleus pulposus (Schmorl and Junghanns, 1971). Figure 1.4.3a shows the variety of manifestations of disc degeneration that can be seen in the vertebral column, including Schmorl's nodes, limbus vertebra and Scheuermann's disease.

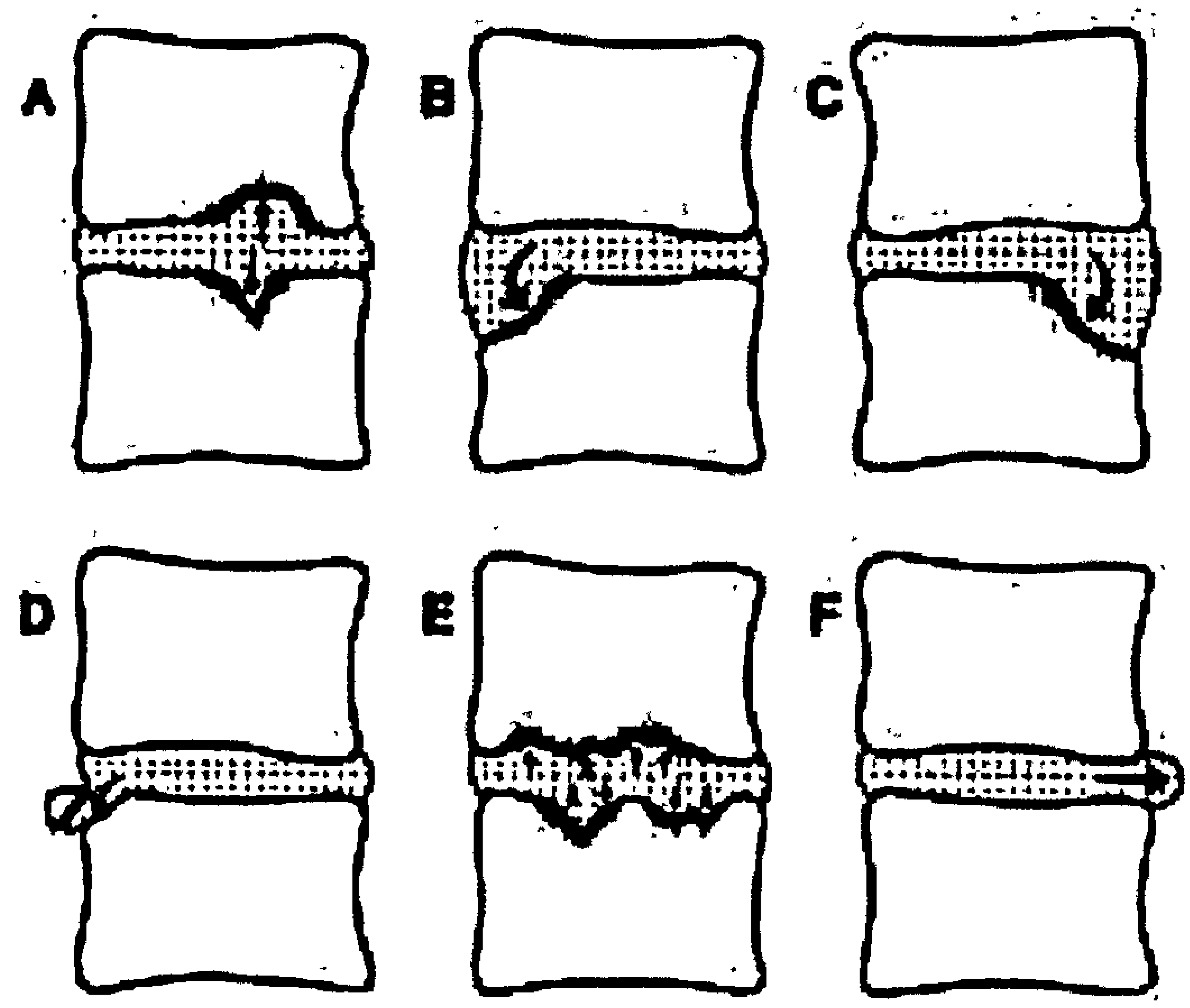


Figure 1.4.3.a: The forms of disc degeneration that can be seen in the vertebral column. A- Central Schmorl's node, B- Anterior Schmorl's node, C- Posterior Schmorl's node, D- Limbus vertebra, E- Scheuermann's disease, F- Disc extrusion. From Swischuk et al, (1998, pp 336.)

i) Clinical Identification of Schmorl's Nodes

The presence of pain in the spine, with or without radiating pain in the lower limb can be caused by Schmorl's nodes, and the diagnosis of the lesion can be confirmed by radiographs, CT scans, MRI scans and discography (Peng *et al.*, 2003, Schmorl and Junghanns, 1971, Swischuk *et al.*, 1998). Schmorl's nodes appear clearly on radiographs, particularly where the lining of the lesion is ossified as this sclerotic bone is easily distinguished from the normal contours of the vertebral surface. In discography, the introduction of contrast medium into the region of the vertebral column in question distinguishes vertebrae with Schmorl's nodes from normal vertebrae as the radio-opaque contrast medium leaks into the lesion from the disc space. MRI scanning may be the best method of identifying Schmorl's nodes in patients, as up to 66% of Schmorl's nodes may not be visible on plain radiographs (Hamanishi *et al.*, 1994). Very small Schmorl's nodes, less than 0.5 cm^2 are even less likely to be visible *in vivo*, but can be identified in bone specimens and cadavers (Malmivaara *et al.*, 1987).

Disc herniation or prolapse is the most common disc disorder seen by spinal surgeons (Urban and Roberts, 2003), but the majority of these herniations are posterior or posteriolateral, causing pressure on the spinal canal, rather than superiorly or inferiorly into the vertebral surface and causing Schmorl's nodes. In contrast with the former type of herniations, herniations of the disc into the vertebral surface can be less symptomatic, and may be entirely asymptomatic. The relationship between Schmorl's nodes and pain is not fully understood; a study of MRI (magnetic resonance imaging) findings from patients with symptomatic and asymptomatic Schmorl's nodes found that in the patients with symptoms, the vertebral bone marrow surrounding the Schmorl's node was inflamed. However, in the asymptomatic patients no inflammation was seen, possibly indicating that, as the inflammation associated with the Schmorl's node subsides, the symptoms also cease (Takahashi *et al.*, 1995). Surgical removal of vertebral surfaces affected by Schmorl's nodes, excision of the disc and fixation of the vertebrae relives pain in symptomatic cases, suggesting that movement of the vertebral column in a region affected by Schmorl's nodes is a cause of pain (Peng *et al.*, 2003).

Although degeneration of the intervertebral disc is asymptomatic in many cases, it can cause other pathological changes and be influential in the development of other conditions. Degeneration affects the height of the disc and hence influences the mechanics of the whole spinal column; it can also affect the function of the spinal muscles and ligaments (Urban and Roberts, 2003). Schmorl's nodes have been implicated in Scheuermann's disease, a kyphosis of the spine common in children and adolescents. In this condition, numerous small herniations of the disc occur, producing a lesion with a different appearance to Schmorl's nodes (Figure 1.4.3a), which occurs over wide regions of the vertebral column (Swischuk *et al.*, 1998). Degeneration of the intervertebral discs in Scheuermann's disease leads to pain, loss of disc space, wedging of the vertebrae and anterior curvature of the vertebral column in the region of the lesions (Schmorl and Junghanns, 1971), but it has been argued that the lesions see in the vertebral surfaces in Scheuermann's disease are a feature of the condition, rather than a direct cause (Resnick and Niwayama, 1978).

ii) The Aetiology and Epidemiology of Schmorl's Nodes

Although the aetiology of Schmorl's nodes is not fully understood at present, many factors have been implicated in their formation, such as age related degeneration of the disc, single incidences of violent trauma (car crashes, heavy falls, direct trauma to the spine), small scale repeated trauma (lifting, bending, smaller falls or jolts), congenital weakness of the vertebral surface or as the result of other diseases (Resnick and Niwayama, 1978, Schmorl and Junghanns, 1971). As mentioned above, Schmorl and Junghanns (1971) argued that herniation of the intervertebral disc tissue into the vertebral surface can only occur where there is a pre-existing weakness of the cartilaginous end plate, and suggested a variety of causes of these weaknesses; some of these theories have been supported by the findings of other researchers. The development of the intervertebral disc may play a role in the formation of weaker regions in the end plate, as the location of the former chorda dorsalis and the vessels, which permeate the disc during development, may leave indentations or scars in the end plate, which may then predispose the end plates to damage (Schmorl and Junghanns, 1971). In a study of normal vertebrae and discs and those with Schmorl's nodes, the specimens with Schmorl's nodes had a significantly greater proportion of disc marrow contacts than the normal vertebrae (McFadden and Taylor, 1989), supporting the concept that developmental factors are significant in the formation of Schmorl's nodes.

Sex

In modern populations, Schmorl's nodes appear to be relatively common; Schmorl and Junghanns reported observing the lesions in 39.9% of males and 34.3% of females at autopsy (Schmorl and Junghanns, 1971 pp 164). More recently, a survey using MRI has shown that Schmorl's nodes were present in 38% of the vertebral columns under study, (Stäbler et al 1997, cited in Jurmain 1998, pp 166) and a study of 100 cadaver vertebral columns found that 58 individuals had at least one Schmorl's node, and 41 had multiple lesions (Pfirrmann and Resnick, 2001). Degenerative changes to the disc, including Schmorl's nodes are seen more frequently and with greater severity in males than in females, particularly in individuals over the age of 65 years (Goh *et al.*, 2000).

Age

The relationship between increasing age and the aetiology of Schmorl's nodes appears to be complex. The lesions can occur from adolescence through to old age; in the young, herniation of the disc is often attributed to the presence of weak areas in the disc end-plate rather than other factors, while in older individuals the disc is thought to be more prone to prolapse due to biochemical and biophysical factors (Chandraraj *et al.*, 1998). Pfirrman and Resnick (2001) found that the prevalence of Schmorl's nodes was similar in an elderly sample to that seen in younger populations. The prevalence of end plate lesions in the thoracic vertebrae increases with age, particularly in the lower thoracic vertebrae, but the relationship of these lesions with increasing age is not as prominent as that seen in other degenerative changes in the disc (Goh *et al.*, 2000). The intervertebral discs degenerate with advancing age, becoming more fibrous and more disorganized in structure, and more frequently affected by tears (Urban and Roberts, 2003); it may be this increase in tears that permits the formation of Schmorl's nodes in older individuals. The appearance of Schmorl's nodes in juveniles and young adults can vary from those seen in mature and older adults; in juveniles, the lesions are often more concave or funnel shaped than the more irregularly shaped lesions seen in older individuals. It is possible that these lesions seen in juveniles have a different aetiology, and may be due to developmental defects rather than degeneration or mechanical factors (Schmorl and Junghanns, 1971).

Genetic Factors

There appears to be a strong genetic factor in degeneration and herniation of the intervertebral discs; twin studies of disc degeneration in the lumbar vertebrae suggested that genetic factors may explain between 26 – 73% of disc lesions (Rannou *et al.*, 2003). In a further study of identical twins, the patterns of disc degeneration were similar in the vertebral columns of the twins even where there were differences in other factors such as smoking or the level of heavy work undertaken (Urban and Roberts, 2003). Studies in Japan have shown that a family history of disk herniation was a risk factor for the development of juvenile lumbar disc herniation (Matsui *et al.*, 1992). If Schmorl's nodes are the result of pre-existing weaknesses in the disc endplate, it is conceivable that these weaknesses are due to genetic factors which affect the formation or stability of the endplate. Bone mineral density may have an impact upon the formation of Schmorl's nodes. While lesions have been identified in individuals with high and low bone mineral content, low bone mineral content is associated with higher numbers of Schmorl's nodes, which are more irregular in appearance than those seen in individuals with higher bone mineral density (Hansson and Roos, 1983).

Physical Activity

It is likely that mechanical factors play an important role in the degeneration of intervertebral discs and Schmorl's nodes, as the intervertebral discs are constantly under loaded by the weight of the body and by muscle activity. Pressure in the disc is greatest when sitting or carrying weights leaning forward, and lowest when lying down. The pressure on the discs increases by four to five times in the transition from lying down to standing (Bibby *et al.*, 2001). However, functional stresses alone are not sufficient to cause disc herniation; animal models have shown that intense exercise does not appear to cause damage to the discs (Urban and Roberts, 2003), and it is most likely that a combination of physical and mechanical factors are involved in the aetiology of disc degeneration and herniation (Rannou *et al.*, 2001). However, increasing the intensity and/or frequency of axial compression causes endplate fractures and Schmorl's nodes (Rannou *et al.*, 2001). Severe traumatic events, such as motor vehicle accidents have been shown to result in Schmorl's nodes, particularly in association with other spinal injuries (Fahey *et al.*, 1998). In this autopsy study, vertebral columns from motorcyclists had the highest percentage of Schmorl's nodes, suggesting that axial loading was a significant factor, and the majority of lesions were observed in the region of T8 to L1, indicating that this region of the vertebral column was the most susceptible to traumatic stress (Fahey *et al.*, 1998), a theory which is supported by the findings of autopsy studies (Malmivaara *et al.*, 1987). The role of mechanical forces in the aetiology of these lesions is clearly complex; the stresses of daily life seem unlikely to be a major cause of the lesion, but episodes of more severe stress, or exposure to sudden changes in force, appear to be an important factor.

Although Schmorl's nodes are seen frequently in radiographs, scans and at autopsy, in the majority of cases they are asymptomatic and, consequently, the clinical literature regarding the epidemiology of these lesions is sparse. However, the literature regarding disc degeneration and prolapse is considerable and, as Schmorl's nodes are the result of disc prolapse, it is conceivable that many of the causes of symptomatic disc prolapse are also applicable to the aetiology of Schmorl's nodes. It must be borne in mind that the aetiology of Schmorl's nodes must differ from anterior and posterior herniations, as the forces required to herniate the disc inferiorly or superiorly, as is the case in Schmorl's nodes, will be different to those which cause herniation in other directions. Disc herniation is itself common, and may also be asymptomatic; a recent MRI study of the cervical spine in 30 asymptomatic volunteers found 50% of the sample had protrusions of the cervical discs, and 37% of the sample had annular tears in one or more of the cervical discs (Ernst *et al.*, in press).

The majority of the research into the epidemiology of disc degeneration relates to the influence of mechanical forces and occupationally related and sporting activities. Heavy physical work, lifting, truck driving have all been implicated as risk factors for back pain and degeneration (Urban and Roberts, 2003). Amongst student nurses, back pain was most common after 9 to 12 months of active training, during which time the students were likely to have undertaken more heavy lifting than they were previously exposed to (Adams and Dolan, 1997). Back pain and spinal abnormalities are common amongst athletes and sportspeople, and an MRI study of young cricket fast bowlers found that, over a period of 2.7 years, the occurrence of disc degeneration increased significantly, particularly amongst bowlers who employed a mixed technique which places greater stresses upon the spine (Burnett *et al.*, 1996). There is a general consensus in the clinical literature that mechanical factors play a significant role in the aetiology of disc herniation and Schmorl's nodes, but it is also clear that mechanical forces are not the single cause of these lesions, and other factors such as age and sex must be taken into account in the interpretation of these lesions in archaeological material.

iii) Archaeological Identification of Schmorl's Nodes

Schmorl's nodes are relatively easy to recognise in archaeological material due to the characteristic nature of the lesions (Rogers and Waldron, 1995), and in the majority of studies these lesions are reported on a "present or absent" basis. Few studies have attempted to interpret the lesions on the basis of severity or location in the vertebral surface, an exception being the work carried out by Saluja et al (1986), where Schmorl's nodes were assigned to one of nine regions on the inferior and superior surfaces of the vertebrae (Saluja *et al.*, 1986). This study found that while Schmorl's nodes were seen in seven of the nine regions, the central region was most frequently affected in the sample from 19th century London, and the posterior region of the vertebral surfaces were most frequently affected in the vertebral columns from a medieval sample from Aberdeen (ibid, pp 93). However, the authors did not propose any explanations for the difference in the location of the lesions between the two samples.

Where the patterns of Schmorl's nodes in archaeological material are to be used as indicators of activity related stress, it is important to distinguish Schmorl's nodes from the lesions seen in Scheuermann's disease, as mechanical stress is less likely to be a factor in the aetiology of Scheuermann's disease. While Schmorl's nodes are most frequently observed in the centre or posterior of the vertebral surface, the lesions of Scheuermann's disease are located in the anterior portion of the vertebral surface, and are more likely to appear as multiple indentations or deep ridges in the vertebral surface, rather than the single lesions of Schmorl's nodes (Swischuk *et al.*, 1998). Scheuermann's disease also affects multiple vertebrae, while Schmorl's nodes can affect only a single surface, and in cases of Scheuermann's disease there may be kyphosis of the spine, which can be identified when the vertebral column is reconstructed. As with all conditions used as indicators of activity related stress, in archaeological material, it is vital to examine the pattern of lesions in order to exclude cases that are the result of pathology rather than mechanical stress. Schmorl's nodes should also be distinguished from the changes resulting from avulsion lesions of the vertebral endplates, which differ in both aetiology and appearance (Maat and Mastwijk, 2000).

1.4.4: Asymmetry

While asymmetry may be the result of pathological or developmental conditions, it is not considered to be a pathology in the same sense as the conditions which have already been examined in this chapter. Consequently this section will not follow the same pattern as the preceding sections, but will focus upon the possible causes of asymmetry in the human skeleton, the variations in asymmetry that have been observed in living populations and the methods used to examine patterns of asymmetry in skeletal material.

Bone is a living tissue and is capable of responding to mechanical stresses, particularly under the cyclical stresses caused by movement. Wolff's Law of bone remodelling states "every particle of mature bone is very active. Such activity must appear in the external shape of the bones" (Wolff, 1892). The three main concepts upon which Wolff's Law depend are that bone is deposited and re-absorbed in order to maintain a balance between strength and weight; that the trabeculae in cancellous bone will become aligned with the direction of the principle stress to which they are exposed; and that both of these phenomena occur as a response to mechanical forces (Pearson and Lieberman, 2004). This law has been integral to the study of the response of living bone to mechanical stress, and the majority of modern studies of the influence of activity upon bone morphology are based around this concept. The primary functions of bone are to be strong and rigid enough to support the body and permit movement, but at the same time to be flexible enough to resist breaking under ordinary levels of stress, and to permit growth. Bone achieves these functions by being capable of increasing its mass or changing its geometry to increase strength, and also by being sufficiently elastic to yield and bend a little under stress. Asymmetry in the size and shape of paired bones can be the result of differences in the level of stress to which the bone is exposed, or differences in the ability of the bone to respond to stress.

The presence of asymmetry in organisms that are normally bilaterally symmetrical has been linked to genetic factors, variations in conditions during development, disease, trauma, physical, nutritional and environmental stress (Gray and Marlowe, 2002, Milne *et al.*, 2003). It has been established that in humans the right humerus and forearm tends to be larger than the left, and that the left femur tends to be larger than the right (Arnold 1844, referenced in Stirland 1993). Studies of human foetal material have shown that the total weight of the muscle and bones was greater in the right side in nine of ten foetuses examined, but the pectoralis major muscle was heavier on the non-dominant side in all cases, while in adults this muscle is larger on the dominant side (Pande and Singh, 1971).

These findings suggest that the greater size of the right upper limb is predominantly the result of genetic or developmental factors, but that environmental factors then influence muscle mass and asymmetry throughout life. In contrast with the upper limb, the pattern of asymmetry in the lower limb does not usually correspond with the pattern seen in the upper limb (Chhibber and Singh, 1971).

Asymmetry in the size and robusticity of long bones has been suggested to have links with handedness and patterns of activity, as has the biomechanical analysis and cross-sectional geometry of long bones. Experimental studies in animals have shown that alterations to bone loading and increases in levels of exercise lead to changes in bone mass, cross sectional geometry, and structure (Goodship *et al.*, 1979, Jones *et al.*, 1977, Woo *et al.*, 1981). Low levels of loading can lead to resorption of bone; astronauts can lose up to 7% of their skeletal mass as a result of periods in zero gravity (Baldwin *et al.*, 1996, Collet *et al.*, 1997).

Handedness, or the preferential use of one hand of the other for certain tasks, is thought to be a major cause of asymmetry in the upper limb, as the higher levels of stress to the preferred side lead to an increase in the size of the muscles and bone. Humans are unusual amongst mammals in that the upper limb is not involved in the process of locomotion, and consequently the bones of the arms do not need to be as bilaterally symmetrical as the bones of the lower limb (Ruff, 2000a). The vast majority of humans have a 'dominant' hand, which is stronger, more dextrous and preferred over the other in the performance of most tasks (Roy *et al.*, 1994). The ratio of left and right-handed individuals varies between populations and through time, but the figures are usually between 84-90 % of the population expressing a preference for the right hand, 2-16 % preferring the left hand. Most populations also include a very small number of individuals who are ambidextrous, having no hand preference in most tasks (Steele, 2000).

Handedness may be culturally acquired, particularly where hand preference in writing is used as the defining criterion (Peters, 1991), but there is also evidence that the high frequencies of right-handed individuals in all cultures are primarily the result of biological rather than cultural factors. Analysis of methods of stone tool production and micro-wear, together with studies of early hominid tooth wear patterns, indicates that dominance of the right side has been present throughout human evolution (Bermudez de Castro *et al.*, 1988, Rugg and Mullane, 2001, Toth, 1985). In a study of the bones of chimpanzees, the left humerus was significantly larger than the right, while the right second metacarpal was larger, findings that correlate well with chimpanzee behaviour, where the body weight is supported on the left arm to free the right hand for manipulative tasks (Sarringhaus *et al.*, 2005). Interestingly, 95% of right-handed individuals have hair that swirls in a clockwise direction, while the hair of left-handed and ambidextrous are equally likely to swirl in either direction, suggesting that handedness is genetically determined (Klar, 2003). It has been suggested that variations from the "normal" proportions of right and left dominant individuals could reflect differing patterns of mechanical usage (Roy *et al.*, 1994). Muscle size correlates well with bone mass, with larger muscles equating to larger bones, particularly in males (Pearson and Lieberman, 2004), so it seems reasonable to assume that individuals with larger bones also have larger muscles, and that asymmetry in bone size should be reflected by asymmetry in muscle mass.

i) Clinical Studies of Asymmetry

As asymmetry of the lower limbs is seen infrequently and does not appear to correspond to handedness, the majority of clinical studies of patterns of asymmetry have examined the bones of the hand and the upper limb. The landmark study of the relationship between activity and asymmetry was that carried out by Jones et al in 1977, which compared radiographs of the humerus from the playing arm of 84 professional tennis players, with those from the non-playing side, and identified a significant increase in the cortical thickness on the playing side, in both men and women (Jones *et al.*, 1977). It has been argued that the findings of Jones et al were the result of injury and inflammation to the arms of the tennis players, rather than from bony responses to differential loading, as 45% of the players involved in the study had suffered from chronic pain in the dominant arm (Bertram and Swartz, 1991). However, more recent studies have supported the findings of Jones et al; a CT scan study of the humeri and radii of 12 male retired national level tennis players from Finland, without chronic elbow pain, found that the levels of asymmetry in the mid and distal humerus were significantly greater than non-playing controls (Haapasalo *et al.*, 2000). A similar study of the humeri of female tennis and squash players found that asymmetry in the tennis players was significantly greater than controls, particularly in girls who had started before or at puberty (Kontulainen *et al.*, 2003). Although studies of the impact of sporting activity upon asymmetries in the lower limb are less common, it has been demonstrated that bone mineral density is greater in the leg used for take off in sports that involve jumping, such as volleyball and gymnastics (Chilibeck *et al.*, 2000), suggesting that differences in the levels and types of mechanical forces the legs are subjected to can affect the patterns of asymmetry in the lower limb.

The ability of bone to respond to mechanical loading varies throughout the lifecycle, with the adolescent growth spurt providing the peak conditions for the development of strong, robust bones (Pearson and Lieberman, 2004). A re-assessment of the data collected by Jones et al (1977) found that the age at which individuals began playing tennis correlated significantly with the degree of asymmetry seen in the humeri, with individuals who began playing earlier developed relatively greater robusticity of the playing arm, which was maintained into adulthood (Ruff *et al.*, 1994). The majority of more recent studies of the impact of physical activity and bone remodelling have examined patterns of bone mass and bone mineral density in females, as loss of bone mineral density and strength leading to osteoporosis is most common in females, and poses a major problem for Western societies where the proportion of post-menopausal women is increasing. A series of studies carried out on girls in Finland (reviewed by Pearson and Lieberman, 2004 pp 85-6) found that the age at which the girls began playing tennis or squash had a significant impact upon asymmetry of the humerus; girls who began training before the age of menarche developed an asymmetry in bone mineral content in the humerus that was twice as large as that seen in controls. Other studies of ballerinas (Khan *et al.*, 1998), and gymnasts (Bass *et al.*, 1998) found very similar associations between age of onset of activity and bone mass and density.

The bone mass that is built up during childhood and puberty can be maintained and built upon during adulthood, if physical activity is continued throughout the adult life. Older females (mean age 57.4 years) have been shown to have a greater degree of asymmetry in the bone mineral density between the dominant and non-dominant arms than younger females (mean age 20.9 years), a difference which was attributed to high levels of physical activity during childhood together with continued physical activity over the lifetime (Chilibeck *et al.*, 2000). In contrast, a study of the pattern of asymmetry in the humerus and tibia from a Californian archaeological skeletal sample found that, in both sexes, the degree of asymmetry seen in both the humeri and tibiae decreased with increasing age (Ruff and Jones, 1981). Ruff and Jones argued that the decrease in asymmetry seen in older individuals was the result of "an increasingly *symmetric* use of the limbs, decrease in activities strongly favouring one limb or decrease in overall activity levels" (Ruff and Jones, 1981 pp 83). However, as the specific patterns of habitual activities undertaken by archaeological populations are unknown, and cannot be attributed to specific individuals, it is not possible to exclude the impact of other factors such as differential access to nutritional resources for the older individuals, or hormonal factors leading to bone loss. Furthermore, as the criteria used for assigning age at death to skeletal material are not precise, it may not be reasonable to compare the results obtained from archaeological studies with those of individuals of known age. In the study by Ruff and Jones, the authors themselves admitted that the technique used to age the material (the degree of cranial suture closure) was not particularly accurate (Ruff and Jones, 1981).

There is evidence that biological sex influences the response of bone and muscle to mechanical, environmental and nutritional factors. In all human societies, males are larger on average than females, but the degree of sexual dimorphism varies, probably due to genetic and environmental factors (Buffa *et al.*, 2001). Females are more capable of limiting the impact of nutritional stress upon body size, as their bodies need to be able to support pregnancy and breastfeeding even during periods of poor nutrition (Buffa *et al.*, 2001), and studies have shown that males are more sensitive to variations in the quality and quantity of food resources (Stini, 1982). Clinical studies of living subjects and studies of archaeological and anatomical skeletal collections have found that muscle measurements are larger in males than in females (Buffa *et al.*, 2001). Therefore, it is important when comparing measurements of bone size to control for sex.

By examining patterns of bilateral asymmetry rather than individual measurements of the bones, it is possible to control for differences in body size and robusticity that result from sex or genetic factors, as the difference between the two sides of the same individual is being examined rather than absolute measures of size. While the simple measurement of the cross section or diameter of a bone is likely to be large in an individual that is generally large and robust (such as an adult male in comparison with a small gracile female), it is not necessarily the case that larger, more robust individuals will have a greater degree of asymmetry than a more gracile individual. The degree of asymmetry measures instead the difference in size between the paired bones, and hence is more likely to reflect differences in usage between the two sides.

ii) Archaeological Identification of Asymmetry

External measurements, radiographic studies and analysis of bone cross sections have all been used to examine patterns of asymmetry in skeletal material, and there are advantages and disadvantages with all of these techniques. External measurements are quick, easy and cheap to take and cause no damage to the bone concerned, but require the bone to be relatively complete. However, they may be affected by external features of the bone such as enthesopathies, infections and trauma, and taphonomic changes such as erosion of the cortical bone or compression and crushing of the bone resulting from burial under a great weight of soil, or the collapse of stone grave structures. Where pathological changes such as fracture or infection are observed, or the bone is clearly affected by taphonomic factors, measurements should not be taken.

Despite these problems, external dimensions of long bones do have a relationship with cross-sectional geometric values; where the external dimensions of a bone are large, the geometric values are also high, particularly second moments of area (Larsen, 1997). The external dimensions of bones are most likely to reflect the patterns of loading which affected the bone shortly before and during puberty, but may not be so representative of changes that took place during adulthood, as mechanical stress affects the proportions of cortical bone to medullary cavity more than the overall size of the bone in adulthood (Pearson and Lieberman, 2004, Ruff *et al.*, 1994, Trinkaus *et al.*, 1994). Radiographic and computer tomography (CT) studies of skeletal material do not suffer from the ethical issues which restrict the use of this technique on living subjects, as exposure to x-rays and CT scans does not damage bone. Bi-planar radiographs can be used to estimate cross-sectional areas, and measurements of external length and diameter can also be taken, while CT scans can give an image of the cross section of the bone. However, where radiographs are used to take diaphyseal measurements, and particularly to examine bilateral asymmetry, the study must control for potential magnification/reduction and distortion of the image, by ensuring that the source-image distance and object-image distance are carefully controlled for each pair of elements (Nystrom and Buikstra, 2005 (in Press)). Radiographs and CT scans require specialist equipment, are expensive and may not be feasible where funds are limited or a large number of bones are to be examined.

Direct measurements of the bone cross section provide a solution to the problems of distortion and magnification which can affect radiographic studies, and allow measurements of the thickness of cortical bone to be taken. Variations in the thickness and morphology of the cortical cross section may provide a more accurate picture of the impact of physical stress upon bone than external measurements of the whole bone, including the medullary cavity (Pearson and Lieberman, 2004); they are also likely to reflect patterns of loading during growth as well as during adulthood (Ruff *et al.*, 1994). However, to obtain a direct view of the cross section the bone must be cut, or in cases where the bone is already broken, the ends may need to be "neatened". Therefore, this technique requires the bone to be damaged, which may reduce the potential for future research, and may not be permitted by the curators of a skeletal sample.

Many different bones have been used to study asymmetry, including the bones of the hand, elements of the skull, the clavicle, and the bones of the upper and lower limb. The humerus and femur are the most frequently used, probably due to the size and robusticity of these elements, which means these elements are more likely to be well preserved in archaeological skeletal material. The location of measurements used to identify patterns of asymmetry also varies from study to study. While measurements are often taken to identify asymmetries in length (Stirland, 1993), the fragmentary nature of archaeological material often means that it is not possible to record total bone length, so the majority of studies have focused upon the diaphyseal diameters (antero-posterior and medio-lateral) and measurements of circumference.

The locations used to measure diameter and circumference, and to take measurements of the cross sections of bones, range from 20% of the total length to 80% of the total length (Rhodes and Knüsel, 2005), but are most commonly taken at 35% and 50% of the total bone length (Mays, 1999, Ruff, 2000b, Steele, 2000, Steele and Mays, 1995, Weiss, 2005). In radiographic studies of cross-sectional geometry, the region of the humerus at around 35% of the total length is most commonly used as this region of the bone is relatively free from other structures, such as entheses, which can cause shadows (Ruff and Jones, 1981). The region at 50% of the humeral length coincides with the deltoid, so can be enlarged by enthesopathies but, in studies of muscle action upon bone, this may not be a disadvantage for this location. In the femur, the region at 50% of the total length is most commonly used as, again, there are few structures present, and it is easy to locate. The section at 80% of length of the femur is also measured in some studies, but the rationale for the choice of this location is not given, and the results for this region are similar to those obtained from the measurements at 50% of the total length of the femur (Ruff, 2000b). Generally, there do not seem to be specific reasons for the selection of locations to be measured, so ease of identification in whole and fragmentary material and frequency of preservation favours the sites at 35% and 50% of length.

1.5: Summary - Musculoskeletal Stress Markers

This section has reviewed the clinical research relating to the conditions that are used as skeletal indicators of activity related stress in the present study, and some of the problems associated with the methods used to identify and interpret these conditions in archaeological skeletal material. Although there is clinical evidence to suggest that physical activity may be a factor in the aetiology of all these changes, physical activity is not the only cause. Therefore, when these changes are used to infer patterns of activity related stress in archaeological skeletal material, caution must be exercised, and the potential influence of other factors must be taken into account. Where the influence of other factors can be excluded, physical activity is a likely cause of all of these changes to the skeleton. The relative reliability and advantages and disadvantages of each of the changes used as indicators of activity related stress in this study are summarised below:

Osteoarthritis – Has an uncertain aetiology- the condition is more prevalent with increasing age, and may be secondary to trauma. Osteoarthritis has a genetic component, which may influence the results in studies of closely related individuals. It is relatively easy to distinguish from other joint disease where eburnation is present and may have a strong activity induced element in the aetiology, particularly from repetitive, high impact and high intensity activities. The condition can be painful and debilitating, so the presence of OA may restrict the ability of the individual to undertake some physical activities.

Enthesopathies – These changes have an uncertain aetiology and are more prevalent with increasing age. Changes to the entheses may be the result of other pathological conditions such as DISH, but examination of the whole skeleton can help to exclude individuals with these conditions. Where other causes can be excluded, these changes may reflect direct stress to the muscles and hence be useful as indicators of activity related stress

Schmorl's nodes – There is no apparent increase in prevalence with increasing age and they are easy to identify in skeletal material. Schmorl's nodes are often asymptomatic in living patients so the presence of these lesions is unlikely to affect the continuation of habitual activities. Physical stress to the vertebral column is likely to be a strong factor in the aetiology. Differences in the locations of Schmorl's nodes in the vertebral column between groups may indicate differences in activity patterns.

Asymmetry – Studies of sportspeople have shown strong associations between levels of activity and the degree of asymmetry seen in the bones. This MSM may be more indicative of activity levels during youth than in adulthood, but asymmetry developed in youth can persist into adulthood, so asymmetry may be useful in the identification of individuals who began physical activities at a young age. Asymmetry may give an indication of handedness and hence could be used to identify variations in the "normal" proportions of right and left handed individuals that may be the result of patterns of limb use. Measurements of the bones are less subjective than the identification of other pathological changes

The following section will discuss the importance of social status in Early Medieval England, the interpretation of social status from burial practices and grave goods and will explore the methods used to infer differences in social status in archaeological populations.

Chapter Two: The Inference of Social Status in Early Medieval Populations

2: The Inference of Social Status in Early Medieval Populations

Status is a significant part of human societies; many aspects of life can be affected by an individual's position and role within society, and the individual's place in society is in turn influenced by factors such as age, sex, heredity, kinship and ability, forming the individual's "social persona" (Binford, 1972). In many modern and ancient societies, the social persona and hence status of an individual is closely linked with biological sex, gender and age. For example, age and biological sex restricted the right to vote in British history, while age still affects the right to vote in modern Britain. In ancient Greece and in the Roman Empire, the difference in status and roles between males and females was marked, regulating many daily activities (Synek, 2000). Status can also be related to ownership of property, kinship or place of birth; for example, in ancient Athens, where only male citizens who were also the sons of citizens had the right to play a part in the democratic process (Bury and Meiggs, 1975). Status and gender can influence the habitual activities carried out by individuals within a society. Both the historical and archaeological sources suggest that Early Medieval society was ranked, rather than egalitarian, with a small number of individuals holding power (Peebles and Kus, 1977).

The following chapter will explore the study of social status in Early Medieval archaeology, and the methods that have been used to identify social differences within Early Medieval cemetery samples. Sex and gender, age, social status, religion and beliefs and ethnicity all appear to have been important influences upon burial practice, and each of these factors will be considered in Section 2.1. The biological aspects of the social persona may have an impact upon the expression of MSM in the skeleton, and hence these factors are relevant for understanding changes in the skeleton that may be the result of differences in activity due to differences in status. Throughout this chapter the term "Early Medieval" will be used, rather than the more controversial, and probably less accurate term, "Anglo-Saxon". "Anglo-Saxon" refers to a specific cultural group- the Angles and the Saxons as defined by Bede, or an unknown number of individuals who came to Britain as an invasion force or as part of a migration from the continent (Carver, 1994, Colgrave and Mynors, 1969). Archaeologically, it is difficult to differentiate people who have adopted "Anglo-Saxon" culture and burial practices from those who are ethnically "Anglo-Saxon" on the basis of isotopic evidence, in fact recent work has suggested that immigrants my be identified by a lack of grave goods in comparison with others in the same cemetery (Budd *et al.*, 2004). In contrast, the term "Early Medieval" refers to a period of time, from the 5th century AD to the Norman Conquest in 1066, and does not have the same potentially misleading ethnic connotations. For the purposes of this thesis, the term "status" is used to refer to the combined social and personal identity of an individual, unless otherwise defined as relating to a particular factor such as age or sex.

2.1: Social Status in Early Medieval Society

The primary sources of evidence for differentiation within society in the Early Medieval period in Britain are the sizeable corpus of graves that have been excavated across the country, and temporally comparable sites from Europe, and the body of written law and literature that survives from this period. Attributing social status to Early Medieval individuals using evidence from grave goods and burial practice has a long history, closely linked to the history of archaeology itself (Lucy, 2002b). Furnished cemeteries characterised by the presence of weapon burials first appeared in the North West provinces of the Roman Empire in the late 4th and early 5th centuries, the period during which migration or invasion of Germanic peoples from the continent and into Britain is thought to have begun. By the 6th century AD, local variation in the types of grave goods buried with some individuals had developed, particularly in relation to age and sex. This "grammar" of burial has been used by archaeologists and historians to try to identify social groupings within populations, based upon sex or gender, age, role in society and religious beliefs (Halsall, 1995a).

From the 7th century AD changes in burial practice began to emerge, with fewer grave goods included in some burials and the emergence, particularly in the North-East, of isolated well furnished graves (Alcock, 1981, Higham, 1986, Higham, 1993). This change may reflect a transition in society, away from a more "open" society where rank was based upon achievement and towards a more hierarchical "stratified" society with reduced social mobility (Peebles and Kus, 1977). It is possible that this social change may be evident in changes of patterns of physical stress in skeletal samples spanning this chronological period.

Cemeteries demonstrate the presence of a community that chose to bury its dead in a particular manner, and from these archaeological data information about the community can be retrieved. In the Early Medieval period in England, settlement sites are much less frequently identified than cemeteries, and as a consequence the majority of material evidence regarding Early Medieval culture comes from cemetery sites (James, 2001). Although both cremation and inhumation burials took place during the Early Medieval period, this review of burial practice will focus upon inhumation burials, as this is the burial practice most commonly seen in the north of England, and is the rite practiced at all four of the sites chosen for examination in the present study.

Burials frequently include dress fittings and other attached items, and also other objects such as weapons, pottery and wooden vessels, and a wide range of apparently everyday objects (Lucy, 2000). The objects most commonly seen in Early Medieval burials are knives and clothes fittings such as buckles, brooches and other clasps and lace tags, representing the clothes that the dead were buried wearing. Beads and bead strings are also found with many burials, and these can be considered as part of the costume or as jewellery or amuletic items (Owen-Crocker, 1986). The presence of weapons in some graves has drawn a great deal of attention, particularly as they are one of the categories of grave goods which is apparently functional and appears to be related to a known role within Early Medieval society, that of the "warrior" (Härke, 1990). However, the relationship between the presence of weapons in a grave and the involvement of that individual in combat is not as simple as it may appear, as will be discussed below. Unfortunately the nature of archaeology means we can never know the precise reason for the differences in burial practice during the Early Medieval period, but with reference to historical and ethnographic information, we can speculate on what they might mean.

2.1.1: Burial Practice, Sex, Gender and Ethnicity

Burial practice may be an indication of the "social persona" of the individual, the social identity that is constructed from a variety of factors, including sex, age and ethnicity (Binford, 1972). In this section, the associations between burial practice and personal identity will be examined, as the identity of an individual within a group, and hence their social status within their community is likely to depend to some extent upon these factors. According to Dickinson (2002), grave assemblages can be separated into five main groupings; burials with weapons; dress accessories and jewellery; personal equipment such as tweezers, ear scoops and razors; other objects such as vessels, and finally burials which have no grave goods. Of these categories, weapons are found almost exclusively with males, dress accessories and jewellery are most frequently found with females and the other groupings generally show no strong association with sex (Dickinson, 2002, Lucy, 1998, Stoodley, 1999). These apparently sex specific assemblages have been proposed as having a symbolic purpose, associated with gender roles (Stoodley, 1999). It should be noted that "sex" and "gender" are different concepts, and should not be treated as interchangeable terms (Walker and Cook, 1998). Sex is the biological status of the individual, either male or female, while gender is a cultural category and can be independent of biological sex. Although individuals buried with weapons in Early Medieval cemeteries are almost exclusively male, there are some exceptions (Montgomery *et al.*, 2005), and a small proportion of skeletally male individuals are found with "female" gendered grave goods (Drinkall and Foreman, 1998, Sherlock and Welch, 1992).

i) Females

The "female" gendered burials include items predominantly associated with clothing and personal adornments, which are often referred to as jewellery, but in reality many of these items also had a practical function (Owen-Crocker, 1986). Pairs of brooches are frequently found at the shoulders of both female and male burials, and while many of these are highly decorated, the primary function of these brooches was to secure the shoulders of a tubular "peplos" gown in females, and/or a cloak in both sexes (*ibid*, pp 28). Other brooches may be found in the middle of the chest, and it is likely that these secured one layer of clothing to another, particularly where an undergarment was worn. Evidence for an undergarment or a different style of dress comes from the presence of wrist clasps, which are most commonly seen in "Anglian" regions of Norfolk, Lincolnshire, Yorkshire and Northumbria (Owen-Crocker, 1986, Sherlock and Welch, 1992). These objects appear to have fastened the cuffs of long sleeves at the wrists, where they are most commonly found on skeletons. These objects are peculiar to the Anglian areas of Early Medieval England and are associated particularly with the Migration Period, and have been suggested to be the artefact that is most indicative of Scandinavian immigrants (Hines, 1984, Hines, 1998).

The presence of buckles at the waist suggests that leather or textile belts were frequently worn and other objects were sometimes hung from these belts, most commonly a domestic knife, but also items such as latchlifters or keys, girdlehangers, tweezers and toilet sets, combs and spindle whorls. Many of these objects are associated with personal care, and are probably primarily functional, but latchlifters, keys and girdlehangers may have a more symbolic function (Owen-Crocker, 1986). Latchlifters are a simple form of key and may be the keys to a house or a strongbox, while girdlehangers have been described as a representation of a key rather than a functional object (Sherlock and Welch, 1992). Latchlifters are often found in groups of similar or identical shapes, more than would be necessary to open a simple lock, and Meaney has suggested that this may indicate social display. This possibility is emphasised by the fact that groups of latchlifters are usually found with burials that also have a conspicuous display of jewellery (Meaney, 1998). Therefore these objects may have had the symbolic function of emphasising the role of the female as wife and mother, and custodian of the house, as part of the significance of kinship and ancestry in the construction of status (Dickinson, 2002).

Beads are also a common feature of female burial assemblages, and can be found individually or in small strings or possibly sewn onto garments, or in large numbers, strung in festoons between pairs of brooches. Single beads may also have been used as fasteners, or placed on hoops as earrings (Owen-Crocker, 1986). Beads and pendants can be made from glass, faience, shell, bone, jet, amber, quartz and metal, and it has been suggested that the colour and material from which the beads are made may indicate social and temporal variation (Drinkall and Foreman, 1998). It has been suggested that bead strings consisting mainly of glass are associated with earlier burials than those associated with mainly amber bead strings (Lethbridge, 1931). A study of the bead strings from the cemetery at Sewerby, North Yorkshire, found that mainly blue glass and amber bead strings showed chronological and social distinctions, and suggested that blue glass beads may be associated with lower social status (Hirst 1985 pp 75 and 77). Although amber can be found on the beaches in some parts of Britain, it is likely that many amber beads were imported from the Baltic region, but as the amber found on Britain's east coast originates in the Baltic, it is not possible to identify the source of many amber beads (Sherlock and Welch, 1992). Amber in the North East may have been imported, but it could also have been collected from beaches and processed locally. Therefore, in the North East, amber beads may not have been as exclusive and exotic as they may have been in other regions where amber had to be imported. Brugmann (2004) has argued that the regional variation seen in the type and quantity of beads associated with burials is not as pronounced as that seen in brooches, and has demonstrated that the type of beads most frequently seen changes over time, with an abrupt movement away from Continental fashions later in the period (Brugmann, 2004).

Towards the end of the 6th century AD there was a chronological shift in assemblages associated with female "gendered" burials, reflected in the types and quantities of items included in the burials. From the 7th century AD there appears to have been a change in female clothing or fashion, with fewer items of jewellery being found in burials, although beads, animal teeth, Roman coins, some brooches, smaller buckles, strap ends, bags, boxes and chatelaines are still found (Geake, 1997, Owen-Crocker, 1986). It is possible that this apparent reduction in the quantity of jewellery worn by women represents a move away from burial in clothing and an increase in the practice of burial in a shroud, rather than a dramatic change in costume.

Literary sources relating to the status and role of women in Early Medieval society are limited, and tend to relate to women of noble ancestry; little is known about the lives of ordinary girls and women (Chadwick, 1924). Where women do appear in literary sources it is as the wives and daughters of high-ranking men, and laws relating to women determine the woman's status in relation to that of her father rather than her husband, although marital status was also important, with a wife having to obey her husband (Härke, 1997a). However, there is evidence for some women who were apparently high status and powerful; Seaxburh of Wessex (AD 672-3) ruled as queen in her own right, and one woman, Æthelburgh, wife of King Ine of Wessex, may have led an army to destroy Taunton, in Somerset (Chadwick, 1924, Härke, 1997a). Some of the literary and legal sources may correspond to the archaeological evidence for female gender roles in Early Medieval society; the law of Æthelberht (c AD 586 -AD 616) and the 11th century laws of Cnut (AD1016 - 1035) suggest that women were responsible for keeping the keys to their stores and strong boxes (Härke, 1997a). It is possible that the keys, latchlifters and girdle-hangers found in some burials are representative of the wife's role as keeper of the keys. Literary sources refer to the role of women in the keeping and giving of weapons; a bride received gifts of weapons from her husband's family, to be kept until her sons were old enough to receive them (Davidson, 1989). Perhaps the woman of the household's set of keys also controlled access to weapons.

ii) Males

As mentioned above "male" gendered burials are distinguished by the presence of weapons, which can include spears, shields, seaxes and, less commonly swords, arrowheads, axes and, very rarely, helmets and armour (Härke, 1989a, Stephenson, 2002). The spear is the weapon most frequently seen, being present in around four out of five weapon burial assemblages, while swords appear only in around 11% of burials (Härke, 1990). While some burials can include a combination of weapon types, Härke (ibid) has argued that, in the majority of "weapon burials", the combination of weapons does not represent the complete fighting equipment of a "warrior"; where a single spear or spear and a shield are found together, this represents a practical, usable weapon, but in some cases the spear is too small to have been used as a main weapon. Other burials include a shield but no offensive weapon, and even in the burials where seaxes are found, these may not have been used as the main offensive weapon (Härke, 1992b). This suggests that the weapons buried in some Early Medieval male graves do not represent a full set of equipment for a warrior to take on to the next life, but instead is a symbolic gesture. The possible social meanings of weapon burials will be discussed in Section 2.1.2.

Härke has also argued that some pathological changes observed in the skeletons from weapon burials meant that many of these individuals were not capable of bearing the arms that they were buried with (Härke, 1990, Härke, 1992a, Härke, 1992b). Although Härke's thinking is valid, and the presence of weapons in the burials of infants and juveniles supports his theory that weapons were primarily symbolic, the osteological basis of his argument is not sound. He cites that the presence of "spina bifida" in an adult male from Berinsfield, Oxfordshire meant this individual was severely disabled and thus incapable of using the spear and shield with which he was buried (Härke 1990, pp 36). However, this individual had spina bifida occulta, a minor and quite common condition involving incomplete fusion of the neural arches of the sacrum. This condition is usually without symptoms and its presence unknown to the individual affected; it is very different from the debilitating condition of severe spina bifida (cystica) (Roberts and Manchester, 1995). If this individual had actually had spina bifida cystica, in the Early Medieval period he would not have survived to adulthood, as spina bifida cystica leaves the spinal cord exposed to injury and infection, as well as causing paralysis and incontinence (*ibid* pp 36). Furthermore, Härke argues that the presence of osteoarthritis and poorly healed fractures would have prevented other males from using weapons during life (Härke, 1990, Härke, 1992b), but does not recognise the possibility that the status of "warrior", or whatever the presence of weapons in a grave meant, could be continued once the physical ability to carry out the role had been lost. Furthermore, people are very good at adapting to disability and, as the symptoms of OA do not necessarily correlate with the severity of the bone changes (Rothschild, 1997), the changes seen by Härke may not have been disabling.

Osteological evidence that does support Härke's hypothesis can be found in the paucity of weapon injuries in some Early Medieval cemetery sites; there was no evidence for violent injury in the Norton Bishopsmill sample (Higgins, in press) or in the skeletons from Bamburgh; only two individuals from Norton Mill Lane had evidence of trauma (Birkett, 1992) but both of these individuals were buried with weapons. Amongst the Castledyke skeletal sample the frequency of trauma was low, with only two individuals having injuries that may have been the result of interpersonal violence, neither of which were weapon burials. Similar patterns are seen in other sites (Duhig, 1998), suggesting that Härke's observation that there is no correlation between interpersonal violence and burial with weapons is correct (Härke, 1992b). However, the skeletal remains do not always give a true indication of trauma suffered during life; only injuries that affected the bones are visible, so soft tissue injuries are underrepresented. It is possible that individuals buried with weapons suffered injuries that did not leave lasting marks on the bones.

A further explanation for the apparent lack of correlation between burial with weapons and involvement in combat as evidenced by injures can be found in the textual evidence. Military service was an obligation for landed nobles, those without land and commoners, and neglecting military service was a fineable offence, under the laws of Ine of Wessex (AD 688 – 725) (Ine 51(Attenborough, 1922)). This suggests that the men who were buried with weapons may not have been the only individuals to be involved in active warfare. Indeed, it suggests that the individuals who were sufficiently wealthy to be able to pay their fine may have chosen to do so and thus bypass military service. This may explain the lack of weapon injuries in the apparently higher status male burials.

Härke proposes that weapon burial is representative of a myth of “Germanic origins” (Härke, 1997b), and that weapons were included with burials because they formed part of an individual’s personal possessions that could not be passed on as heirlooms, although there is some evidence that some swords and shields had belonged to more than one owner (Härke, 1990). Perhaps in these cases the weapons were spoils of war, so could be used by another individual and did not have to “die” with their original owner. Lillios (1999) has argued that when “heirloom” objects are included in burials this indicates that the heirloom has lost its meaning, that it is no longer as socially valuable, as to hold meaning it must be in circulation and hence will not enter the archaeological record. This suggests that individuals buried with “heirloom” items may represent the end of an ancestral line, where there is no inheritor to pass the heirlooms on to, or a change in the importance of inheritance in the construction of social status, or possibly a shift in the meaning of the objects (Lillios, 1999). In the case of the Early Medieval weapon burials, this argument could be used to explain the apparent lack of correlation between weapon injuries and weapon burials. Perhaps the individuals who did take part in fighting, as evidenced by their injuries, passed their weapons, the symbol of their social identity on to their inheritors, while those buried with their weapons did not have heirs to pass their status on to. Even if this were the case, it would not be possible to identify individuals who took part in warfare but did not suffer injuries, or were not buried with weapons, unless the act of fighting or training left other markers upon their skeletal remains.

Although weapons are the most strikingly "male" grave goods, some males are also buried with more "female" assemblages while others are buried with artefacts that were not particularly gendered one way or the other, such as knives. The significance of "female" grave goods with apparently male individuals is uncertain, although it is possible that some of these cases are the result of inaccurate osteological identification of sex; young males can look like females, while older females can be more skeletally masculine in appearance (Walker, 1995). However, there is some reference in the written sources to differentiation in the roles of males being related to religious beliefs, with priests not being permitted to carry weapons or ride a stallion (Hines, 1997). For some individuals the display of gender through burial practice may not have been as important as it was for others, or there may have been some social reason for burial with objects more usually associated with the opposite sex.

iii) Gender-less burials

Not all individuals in Early Medieval burial grounds were interred with grave goods and hence do not fit into such neat gender roles (Lucy, 2000, Lucy, 2002a). A large proportion of burials from this period were not accompanied by grave goods, or had small numbers of simple items that do not fall into obvious gender categories. Stoodley found that 44% of adults did not have gender specific grave goods and, of these, 40% had no grave goods at all (Stoodley, 1999). However, even amongst some apparently gender-less burials, there is some evidence of gender differentiation amongst knives, as Härke found that knives buried with adult females were consistently smaller than those found with adult males (Härke, 1989b).

If the presence of some artefacts in burials indicated gender, why were there burials without gender specific grave goods, and why were some individuals buried without artefacts? Or, conversely, why were only some individuals buried with these gendered grave goods? Variations in factors other than gender may explain these differences, some of which will be discussed below.

iv) Ethnicity and Status

As mentioned at the beginning of this Chapter, migration of people from the Continent to Britain is thought to have taken place in the period from the 5th to the 7th centuries AD, resulting in the presence of different ethnic groups in Early Medieval England. However, there is much debate over the accuracy of the historical accounts of the migration given by Gildas (circa AD 540) and Bede (AD 731) and the extent to which the cultural changes seen in "Anglo-Saxon" Britain were the result of the movement of people or the movement of ideas (Crawford, 1997, Hamerow, 1997). Much of the variation seen in Early Medieval burial practice has been ascribed to ethnic differences; regional variation in the types of clothing and dress fittings found in burials has been associated with ethnic groups (Hines, 1998, Owen-Crocker, 1986). Some variations in stature and patterns of non-metric traits observed in skeletal material have also been attributed to ethnic differences, although the validity of these traits as indicators of genetic relationships has been challenged (Tyrrell, 2000), and studies of the similarities between the Y chromosome mutations seen in samples of living males from Central English towns and from Norway and the Netherlands has been argued to support a substantial migration of people from the continent to England (Weale *et al.*, 2002).

The possibility that variations in burial assemblages may be due to the presence of different ethnic groups within the same cemetery has recently been examined using analysis of oxygen, strontium and lead isotopes from tooth enamel (Budd *et al.*, 2004, Montgomery *et al.*, 2005). A West Heslerton, in North Yorkshire a group of "non-local" individuals was identified, using variation in strontium and lead isotopes, who may have grown up elsewhere, probably in Scandinavia. However it was not possible to determine whether the isotopic composition of the tooth enamel in these individuals was due to differences in diet (eating food imported from elsewhere) or the result of growing up in a different and unknown location (Montgomery *et al.*, 2005). If these individuals did grow up elsewhere, this was not reflected in their treatment in death; there was no correlation between the ratios of strontium isotopes (87Sr/86Sr) and burial position, the side that the individual was laid on or the grave alignment. There were no correlations between the ratios of strontium isotopes and the categories of artefacts found in the burials (weapons, jewellery, other grave goods and no grave goods), and both local and non-local individuals were seen in all four categories, although the only sword at the site was buried with a non-local individual (Montgomery *et al.*, 2005). Budd *et al* (2004) also examined the burials from West Heslerton, along with burials from Repton in Derbyshire, but this study also explored variations in the oxygen isotopes, which may give better geographical resolution. This study found a better correlation between isotopic and archaeological data at West Heslerton, where all four females identified as being potentially Scandinavian, on the basis of oxygen isotopes, were the only females in the sample to be buried without brooches, and were generally more poorly furnished than the rest of the sample (Budd *et al.*, 2004). The findings of these studies suggest that actual ethnic origin may not be a significant factor in the construction of social identity as expressed through grave goods, or conversely that apparently “Anglian” artefacts are not necessarily indicative of “Anglian” ethnicity.

2.1.2: Burial Practice and Age

There are problems with attempting to identify age related status groups within archaeological populations. Firstly there are issues with applying modern perceptions of the meaning of age towards age groups in the past; the modern definition of a child may be very different to that in an ancient society (Ucko, 1969), although the literary evidence that survives from the Early Medieval period can shed some light on this problem. Secondly there are problems with the identification of age and sex in archaeological populations. Given good preservation of skeletal material it is possible to age juveniles to within a few months of their real age at death (Scheuer and Black, 2000), while younger and middle aged adults are somewhat more difficult to age, and can often only be placed within age ranges of 10 or more years (Bass, 1995). Older adults present even more difficulties as it is not possible to accurately age individuals past the age of around 40 years, and osteological techniques used to ascertain age at death appear to consistently underage very old individuals (Molleson and Cox, 1993). Age and gender appear to have been be closely linked in Early Medieval society (Gowland, 2002), so there will be some degree of overlap between this discussion and that of the impact of sex and gender upon burial practice.

Age is an important factor in the stratification of societies (Binford, 1972), and as with other factors influencing status, age categories in archaeological populations are social constructs rather than representative of biological distinctions (Kamp, 2001). In modern British society, the age of an individual affects their right to vote, to marry, to drive, to leave education or undertake full time work, to drink alcohol and, it also affects the manner in which people are punished for committing crimes. Most of these restrictions are enshrined in law and apply to individuals below the ages of 16, 17 and 18 and represent the legal transition to adulthood. Similar changes in social roles and status with age are seen in other modern societies, recorded historically and inferred in archaeological populations (Ucko, 1969). In the Early Medieval period certain age thresholds were recognised in law; in the 7th century at age ten a child legally became an adult, and by the 10th century this age was raised to 12 years (Crawford, 1991). The laws of Athelstan (AD 925 – AD 939) again increased the age of criminal responsibility to 15, at least in parts of Southern England, with no-one under this age being put to death unless they tried to escape or resist arrest (VI As 12.1 (Attenborough, 1922)). Knowledge of the legal age of adulthood in Early Medieval Britain can go some way towards explaining the inclusion of apparently "adult" artefacts such as weaponry in the graves of individuals that modern society would consider still to be children (Crawford, 1991, Kamp, 2001).

One argument is for the presence of other thresholds that were not recognised legally but do appear in other literary sources such as poetry (Davidson, 1989). Some of these thresholds also appear to be archaeologically visible. The literary sources suggest that at around seven to eight years a child began to undertake light work or education, and may have been fostered outside of the family; noble boys also began hunting and weapon training at this age (Davidson, 1989, Dickinson and Härke, 1992). At around 14-15 years boys entered adult life, and in the case of nobles this may have meant active involvement in warfare or service to a lord, while those of less noble birth were trained as farmers, builders and herdsmen (Davidson, 1989). After around ten years in service, men are thought to have retired to a monastery, served as advisors to kings or taken on the running of the family estate (Härke, 1997a). The majority of the literary evidence refers to men and those of noble birth, and evidence for transitions of status with age that may have applied to women and ordinary men is sparse. In the archaeological record, some children aged between 7 and 14 years were buried with more grave goods than younger children, including dress items, spears, arrowheads and occasionally swords and shields (Stoodley, 2000), and from the age of 15 there is another increase in the number of objects in "female" graves, with a reduction in the number of "males" buried in a flexed position (Härke, 1997a). With skeletal maturity, the orientation of burials becomes more standardised, the frequency of coffins and other grave structures increases, and artefacts such as musical instruments, gaming pieces, horse harnesses, axes and seaxes are found only in mature adult burials (Stoodley, 2000).

Stoodley (2000) and Gowland (2002) have argued that age is a major influence upon burial assemblages in Early Medieval cemeteries, as age affects the degree to which gender is expressed. While gender is recognised early in life by the association of burials with particular types of artefacts, the strength of the symbolism used increases with age. At between ten and twelve years the "female" grave assemblage becomes more complete, including more and different varieties of brooches, a change which Stoodley associates with the beginnings of puberty, and suggests that this marks the "principal change in the female lifecycle" (Stoodley, 2000, pp 463). Although it is not possible to identify the age of onset of puberty in skeletal samples, in the modern world ten years seems a very young age to enter puberty, and it may be morel likely that this threshold represents a social rather than biological change in identity. On the basis of variations in the frequencies of beads in "female" grave assemblages, Stoodley suggests that there may have been another threshold during the late teens, which may have been influenced more by social criteria (*ibid*). Further evidence that female status was not solely dependant upon the ability to bear children is demonstrated by the fact that some older women were buried with a full "female" set of grave goods (ibid pp 465). The archaeological evidence for distinct life stages within "male" gendered burials is more tentative, but there is evidence for some age-related distinctions, as the knives and spearheads in male burials increase in size with the age of the individual. The presence of animal bones in burials may also be related to age and sex, with adults being more likely to have animal bones than juveniles (Lucy, 2002b).

Objects may be placed with the dead to represent the position of the individual in their lifecycle, rather than a static identity. Objects may also represent the transition of the dead individual from a living member of the community to a dead ancestor, or the aspired identity of the individual- the status that they might have achieved had they not died (Williams, 2005). The choice of an artefact to be included in a burial may be representative of the person who deposits the object, as much as the person who is being buried (Williams, 2005). Therefore, it is possible that the weapons and other objects buried with children have belonged to their parents or other close relatives, and represent the status of the family rather than the child, they may have been given as gifts in death rather than being the possessions of the individual in life (King, 2004). If grave goods are, to some extent, representative of the individual's stage in a lifecycle as well as their gender, perhaps the individuals who were buried without gendered grave goods were at some transitional point, which did not permit them burial with gender-specific grave goods. It is also possible that the variation seen both within "gendered" burials, and between burials with and without gendered artefacts, is indicative of differential access to objects, and hence different social groupings within Early Medieval society.

2.1.3: Burial Practice and Social Status

The evidence from burial practice may not be a direct mirror image of the status of an individual during life, but this archaeological evidence, together with limited documentary sources, is the only evidence that archaeologists and historians have to try to reconstruct Early Medieval social identities. Burial of the dead might be an act of "conspicuous consumption" (Halsall, 1995a), an activity that is carried out not only as a method of disposing of a corpse, but also as a means of creating and displaying social identity (Steuer, 1989). In a small settlement, the burial of an individual is likely to have involved the whole community, and hence provided an opportunity for social display, between families and/or between ranks. This "display" may thus incorporate many aspects of the person's identity, such as age, sex and occupation.

Documentary evidence relating to north-eastern England is particularly sparse, so much of our understanding of social structure in this region must be inferred from sources primarily relating to other parts of the country.

i) Textual Evidence

The identification of social structure in the Early Medieval period is both helped and hindered by the presence of written evidence relating to social differentiation. As early as c AD 600 legal documents indicate a complex ranked society, with a number of social ranks ranging from the slaves and peasants to landed nobles and companions of the king.

Although there was regional variation in the number and types of social groups mentioned in the legal texts, some of the social groups seem to have been universal. The presence of slaves in England is undoubted; Bede noted that English slaves were available for purchase in Rome before AD 592 (H.E. II.1) and it is likely that the slave trade was one of the key methods of communication with the Continent (Chadwick, 1924). Northern England was probably a net exporter of slaves in the 5th century AD (Higham, 1986), but could also have come from within the country, as enslavement was utilised as a punishment for crimes such as murder (Adomnan, I, 87b (Reeves, 1857)), theft (Ine, VII, 1) and working on a Sunday (Ine, III, 2). The basis of Early Medieval society was, according to Stenton, the *ceorl* or free peasant landholder (Stenton, 1971) and his rights and obligations were set out in law; the value of the life of a ceorl was between 100 (Aethelberht, XX1) and 200 shillings (Ine XXXIV, 1). In Kentish law, between the ranks of slaves and freemen were the *laet*, who were probably freed slaves, but in other regions the status of a freedman seems to have been the same as those who have always been free (Attenborough, 1922). The ownership of land was a vital component in the construction of social status; one hide (or *hid*, which originally meant a nuclear family) of land was a normal quantity of land for a *ceorl* and his family to work (James, 2001). While a *ceorl* could own land and become wealthy, he could not attain higher social status unless he owned sufficient land. If he prospered and held five hides of land, he could become a *gesith* or *thegn*, a "lord of the manor" (Stenton, 1971) and thegns through service to the king could become *eorls* (Wormald, 1999). The *gesith* or *comes* was a "companion" of the king and a military specialist, while the *ceorl* was not, although both were required to undertake military service (Wormald 1999, pp 461). Stenton argues that in Northumbria an individual's status as a noble, a *gesithcund man*, was based upon membership of the king's bodyguard, and that the gifts of land given by the king to his companions were for their lifetime alone and could not be passed to their heirs (Chadwick, 1924, Stenton, 1971), suggesting that the actions and status of the individual were most significant, rather than any inherited status.

The responsibilities of a king's companion were great; he was expected to fight to the death for his lord, and follow him into exile (Chadwick, 1924). However, the rewards of companionship were also great; gifts of land have already been mentioned and with the land came the food-rent and services of those who worked the land (Stenton, 1971). The companion also shared the hearth of the king, took part in hunting, feasting and drinking and may have received gifts of weapons and jewellery (Chadwick, 1924). The status of a *gesith* seems to have been primarily based upon the accomplishments of the individual. In contrast, the Kentish noble status of *eorl* or *eorlcund man* appears to have been a hereditary one, suggesting that status of men at least could be both inherited and acquired during life. There was clearly room in Early Medieval society for the upwardly mobile, leading to the question of whether these "*nouveau rich*" can be identified in the archaeological record. Perhaps these individuals had a need to express and reinforce their new status in ways that are archeologically visible, such as through burial practice.

While upward social mobility was a desirable possibility, the opposite was considerably less desirable, but equally possible. As has already been mentioned, criminals could be forced into slavery and the land given by the king could be taken away leading to a reduction in social status (Chadwick, 1924). If the bishops and nobles did not obey their king they could be fined and stripped of office (Æthelstan IV: 11 (Attenborough, 1922)).

Despite the wealth of information the documentary evidence has to offer on the subject of social status, there are gaps in the evidence. The majority of documentary evidence for legally defined social status relates to the later phase of this period, where the influence of lordship and Christian kings and the development of land ownership systems may have altered the earlier social structure. It is possible that the social distinctions given in the later documents are not applicable to the earliest phase of the Early Medieval period, and therefore it may not be possible to identify these specific social groupings in Early Medieval cemeteries. Furthermore, the position of women in these ranks is uncertain, although some women in the Early Medieval period held positions of high status in their own right; the social status of the "ordinary" woman is rarely recorded in the existing literature (Thompson, 2004). When women are mentioned in legal documents it is usually as accessories to men; as wives, daughters and slaves. Occasionally though, the lack of reference to women can be used to infer their status; the laws of Æthelstan refer to the exclusion of "poor widows who have no land and no one to work for them" from the payment of a tax for common benefit (IV, 2). This suggests that all other widows, and other women who did hold land were required to pay. Widows with children were also entitled to a share of their husband's wealth (Æthelberht 78), and a woman could leave her husband, take the children and half of his goods (Æthelberht 79), suggesting that at least where children were concerned, the rights of the woman were similar to those of the man. While women were just as likely as men to be punished for wrongdoing (Alfred 18: 1-3 and Æthelstan IV: 6), and could be punished for the crimes of their husbands (Æthelstan IV: 3), it is likely that by obtaining a good marriage they would have been able to move between ranks in a similar manner to men. There was differentiation in the status of women; for example the payment in recompense for lying with the king's maiden was greater than that required for the same offence with a "grinding slave" (Æthelberht 10 and 11), although the level of detail regarding the status of women in the documentary evidence comes nowhere near that of men.

The main documentary sources of evidence for the social structure of Northumbria are Bede's *Ecclesiastical History* and Stephen of Ripon's *Life of Wilfred*, although both of these sources can only really shed light upon the late 7th and early 8th centuries AD. However, they do refer to the existence of royal officials. There were sub-kings, patricians (possibly the king's principal official), dukes, prefects (who may have been responsible for each of the *urbs*), beneath whom were the *gesith* or *comes*; beneath the *gesith* were soldiers of the king, also referred to as *thegns* (Rollason, 2003). While there are some similarities between this social hierarchy and that seen in the Kentish kingdoms, without the support of legal documentation it is difficult to identify if the ranks are equivalent between the regions. The presence of an aristocracy in Early Medieval Northumbria is undoubted. Bishop Wilfred's family was wealthy enough that when he left home at the age of 14, he was able to take with him an armed band of servants on horseback; by the 8^{th} century AD some of the aristocratic families were competing for the throne, and the church was dominated by aristocrats (Rollason, 2003). Rollason argues that in Northumbria the *comes* were established men with property, while the *thegns* or *ministri* (knights) were younger men associated with the king – the household retainers who, after a period of service would be given land by the king and established as *comes* (Rollason, 2003). This pattern is very similar to that seen in the careers of the Kentish *gesith* discussed above; perhaps then the aristocracy in Northumbria are more comparable with the status of *eorl*, where land and wealth seems to be more hereditary.

Having evidence of specific ranks in society leads to the almost irresistible desire to try to identify these groups of people in the archaeological record, but as there is no documentary evidence for how the different ranks of people buried their dead, any connections drawn between the documentary and archaeological evidence can only be tentative.

ii) Material Evidence and Assessment of Status

The scarcity of documents relating to the social structure of the North-East leads to a greater dependence upon the archaeological record for clues as to the nature of society in this region in the Early Medieval period. There is evidence for a degree of continuity of Roman and Romano-Christian practices; inscribed memorial stones from Whithorn (in West Scotland, but likely to have been under Northumbrian influence) show a continuation or re-introduction of Roman methods of commemorating the dead, as does the prevalence of stone lined and cist graves in the region (Higham, 1993). The seats of power in the region; Bamburgh, Edinburgh, Mote of Mark, Dunbar, Dumbarton Rock and Yeavering appear to be based upon earlier fortified centres, suggesting a continuity of power held by local families, rather than incomers. However, Alcock (1981) has used the archaeological evidence to counter this argument; Alcock suggests that the small number of well-furnished graves found in Bernicia indicates a hierarchy of burial practices, with only the Anglian elite performing furnished burial (Alcock, 1981). In contrast, Higham argues that these burials have been influenced by local practices, such as a preference for north-south orientation, and burial in isolated mounds, suggesting that the high status burials were those of the native British who had Anglicised their burial practices, or of Anglians who had added a local flavour to theirs (Higham, 1993). While there is evidence for the upper ranks of society from the documentary sources, and potentially from archaeology, the evidence for "ordinary people" in Northumbria is almost entirely archaeological, coming from the limited settlement evidence and the burials themselves.

Once it is accepted that variation in grave goods and other burial practices is evidence of social differentiation, the primary issue is to decide what these variations actually mean; which are the high status individuals, which are lower status and why this variation in status was present in the first place. A variety of different methods have been proposed to identify and interpret differences in burial practice in archaeological samples. Following the theoretical arguments of the "New Archaeology", Tainter has suggested that the mortuary population and the treatment of the dead reflects the structure of the society in question, and that analysis of mortuary practices can be used to identify the level of organisation and social ranking within society (Tainter, 1977). Where variation is seen in burial practices within a society, those practices that require the greatest expenditure of effort and corporate involvement from the living will indicate the individuals of highest status, and the number of different types of burial will indicate the degree of structural complexity. As the status of the individual is dependent upon the number of other individuals that are subordinate to them, as the rank of the individual decreases, the number of individuals with that rank should increase, i.e. the higher the social status, fewer individuals would be expected to hold that status. Tainter demonstrated this hypothesis using sites from the Middle and Late Woodlands periods from the American Midwest (Tainter, 1977), but it may be applicable to any society where variation in burial practice suggests a degree of social differentiation. In Early Medieval cemeteries there is clearly variation in burial practice, and variation in grave size, shape, depth, location, structure and the number and quality of artefacts included with the individual can all be used as indicators of the energy expended in the process of the burial. Therefore Tainter's model should be applicable to Early Medieval burial sites, and to some extent this seems to be the case; in the cemeteries of the 5th to 7th centuries AD the number of individuals with very elaborate graves and burial artefacts is relatively small, while the number of individuals with less elaborate burials is greater, but at most sites the proportion of individuals buried with grave goods and in complex graves is relatively large (Arnold, 1997).

From the late 7th and early 8th centuries AD the number of different burial practices decreases drastically, as does the number of individuals afforded burials with apparently great expenditure of effort and wealth. This suggests that from the 8th century the number of social ranks decreased and the importance of the highest status individuals increased. However, this model does not take into account the possibility that, from the 8th century, status was expressed in an arena other than that of burial, a possibility which will be discussed further below. It is clear from the documentary sources that towards the end of the 7th century AD Northumbria was politically unstable and that the kings were heavily dependent upon the support of the aristocracy, but a lack of land to give to young nobles to retain their support led to the development of competing patronage systems (Higham, 1986). This apparent change in the local political system may have influenced the degree of social complexity at a local level and hence expressed through burial practice. A desire to secure one's social position in times of change may have led to a reduction in the number of social ranks, in order to reduce competition and maintain control.

Once it has been established that the society is one with distinct social structure, the question of the meaning of each rank arises. A variety of methods of assessing social status in the Early Medieval period are discussed by Härke (1997), the major thrust of these techniques being to try to correlate the various social groupings mentioned in the textual sources with the differences in burial assemblages. However these types of study have been criticised as they do not take into account regional variation and chronological change

(Härke, 2000). Weapon burials have received the most attention in these studies, as a result of the assumption that social rank strictly controlled the ownership of weapons. This has led to the conclusion that swords and seaxes were only owned by higher status freemen, spears were indicative of the lower status freemen and higher status half free, while those males buried without weapons were the majority of the half free and the slaves (Härke, 1997a). Härke noted that males buried with weapons were on average 2.5 to 5 cm taller than males without weapons, perhaps as the result of better health during growth or better nutrition, as a result of greater wealth and better living conditions amongst the elite (Härke, 1992a). Härke has suggested that this stature differential may due to a difference in ethnic origin, but as the error range for the estimation of stature from skeletal material can me as much as +/- 5 cm, it is possible that this difference is an artefact of the methods used to estimate stature (S. Lucy *pers. comm.*).

Although different weapon types may be representative of differences in status, these weapon-based systems of analysing status do not explore the meaning of the burials that did not have weapons, both male and female, and those that include a variety of other items. Other systems have correlated the rich female (and occasionally male) burials as being the same social rank as the male sword burials, while burials with spears were assigned a lower status and equated with burials with brooches and necklaces (Alcock, 1981). Later methods of analysis did not try to directly correlate burial assemblages with named social groups, but instead explored the social meaning of artefacts, in terms of gender, access to traded goods and relative wealth (Härke, 1997a). Analyses of the investment of time and labour in the construction of the grave have also been explored, in some cases finding correlations between the dimensions and structures of a grave and the quality of the grave goods, but in other cases there is no such association (Härke, 2000). This suggests that regional and/or temporal variation had a strong impact upon burial practice, and that it is unlikely that any one system of analysing variation in burial practice will ever be fully applicable over a wide area or between different time periods.

In their analysis of social status at the Moundville sites of Alabama, USA, Peebles and Kus (1977) proposed a system of ranking based upon burial practice, in which the status of the highest ranks is dependent upon genealogy. The very highest class is likely to be entirely composed of adult males, next highest ranking super-ordinate class will include males, females and sub-adults and some of the sub-adults will rank higher than the adults in the lower social groups, highlighting the importance of genealogy over achievement. The subordinate group of individuals will express their status through energy expenditure in the burial and will be ordered on the basis of age and sex, with variability in burial practice within this group reflecting the personal achievement and life history of the individual. In this group, older individuals will hold higher status, achieved over their lifetime – adult burials will be more complex and represent a greater investment of energy than those of children. Female burials will be differentiated from those of males by the types of artefacts, and adult burials will contain different artefacts to those of children (Peebles and Kus, 1977).

While aspects of this ranking system have close correlations with the burial practices seen in Early Medieval England, it may not be appropriate to fully apply this system of ranking to the sites in question. It seems reasonable to correlate the highest rank in Peebles and Kus' system with the Early Medieval kings, and hence the super-ordinate class with an aristocracy, and as the presence of an hereditary aristocracy was not certain in Early Medieval England at the beginning of the period, this method may not be applicable to the earliest sites. However, the description of the super-ordinate class does fit well with the well-furnished male, female and child burials seen at many 5th to 7th century cemetery sites. If this is the case, then the sub-ordinate class may be represented by the less lavishly furnished burials of both sexes. The major problem arises with weapon burials. These are generally entirely male but are not the apex of society, as they are quite common. Their burials may not be well furnished aside from their distinctive artefacts, perhaps suggesting a lower social status. Perhaps instead these burials are evidence of sexual differentiation in the sub-ordinate section of society, but this does not correspond well with the concept that these individuals are "king's companions" as suggested by the documentary sources. Furthermore, this system of ranking may not be directly applicable to sites from the 7th century onwards, where the quantity of burial artefacts is reduced.

In the 1970s and 1980s, basic counts of the number of artefacts present in each grave were utilized to gauge the "wealth" of each burial, and identify individuals of comparatively high, middle and low status (Arnold, 1980). Simply counting the number of artefacts present can lead to disproportional high status in some individuals, such as females buried with large numbers of beads which can be counted individually but should probably be treated as necklaces or bead strings. In this system, "female" burials will almost always be recorded as being "wealthier" and thus higher status than those of males, which may not reflect reality. A means of confronting this issue is to employ a count of the number of artefact types (quantitative analysis or NAT), where each type of artefact is counted once so a spear would count as one item, as would a string of 20 beads (Hedeager, 1992). This method serves to eliminate regional variations to some extent and examines the number of artefacts with different functions, but is dependent upon well-documented and well-preserved burials, and also assumes that a high number of artefact types is indicative of high status.

When a basic count of the number of artefacts is used, a grave with a large number of artefacts will appear to be the wealthiest, but when NAT is used a high number of artefact types may not necessarily indicate a wealthy burial, a score of one could indicate the presence of a single potsherd or three spears. While both these graves only have one type of artefact and hence both may be considered to be relatively poor, the difference in the type of artefact is significant, and is likely to suggest a difference in the social identity of the individuals. Therefore, to identify these differences it is important to use NAT analysis in concert with other methods, to identify the burials that include more prestigious items. Hedeager (1992) has shown that, in the Scandinavian Roman Iron Age, there was a correlation between the number of artefact types in a grave and the quantity of luxury or imported goods, while locally produced goods were evenly distributed amongst burials. This finding suggests that luxury items were controlled by the highest ranking groups, and distributed down to the lower status groups (*ibid* pp 120). Ethnographically, ownership of luxury and exotic goods tends to be restricted to the highest status individuals in society (Peebles and Kus, 1977), and in a society where social position is displayed through the burial of the dead it could be expected that exotic, non-local objects would indicate higher status.

More subjective analyses of grave goods have been undertaken to assess the status of the burial on the basis of the quality and value of the grave goods. In continental archaeology a popular method has been to assign "ranks" to different combinations of weapons and artefacts (Steuer, 1989). These ranks have been equated with the legally defined groups mentioned above; the nobles, freemen, half-free and slaves (Halsall, 1995a). However this technique has mainly been applied to male burials and may be of little use where female burials are concerned. Furthermore, the value of some objects may not be immediately apparent; artefacts may be given a very high social value, but be of low material value, for example amulets and animal bones, and hence the social value of these items may be underestimated, as our perceptions of "value" may be different to those of the population in question.

Steuer (1989) has argued that the attempt to correlate these ranked burial types with the legal ranks is misguided, stating that in continental Europe at least there is no relationship between the tribal rights or *wergeld* of an individual and their socio-economic situation. Therefore, there is no reason to expect the contents of graves to correspond with this legal status; instead burial practice is representative of an individual's lifestyle (Steuer, 1989 pp 105). If this is also the case in Early Medieval England, there are interesting implications for the present study; while an individual's level of physical activity may be influenced to some extent by their social rank, their lifestyle is likely to be a greater factor. To take a hypothetical example, two men may own the same amount of land, giving them the same legal status, but while one has a large group of family members and subordinates to help him work the land, and thus reduce his need to undertake physical labour, the other has only his immediate family and therefore has to take an active part in the upkeep of his property. While the status of these two individuals may be the same, their lifestyle is not, and this difference may be visible both in their burials and their skeletal remains. In Germany and Denmark archaeologists have moved towards an attempt to identify families and kin groups, particularly those considered to be the "nobility". Some of these studies have begun to incorporate the biological data, for example, utilising dental non-metric traits to identify potentially related groups of individuals, together with archaeological evidence for phasing and distinct plots (Härke, 2000).

Considering the many problems with attempting to categorise burial practices in Early Medieval cemeteries, perhaps the most useful method of differentiating between burials in Early Medieval cemeteries is one of the most simple, that of subdividing burials into categories based upon artefact types, with consideration of the possible meanings of specific artefacts. The system proposed by Lucy, which divides burials into four categories; those with weapons, those with jewellery, those with other grave goods and those with no grave goods (Lucy, 2000), has been used in some more recent studies (Montgomery *et al.*, 2005). However, this system does not recognise the variation that is seen between weapon burials and jewellery burials, where both categories can be very varied (see discussion of gendered burials above). Systems of this type do not take into account the cases where burial practice forms a continuum; by defining the groups by the presence or absence of certain objects (such as weapons or horse trappings), continuity of the presence of other artefacts such as knives, buckles and brooches may be obscured. This type of method may enforce categories that do not exist in reality (Steuer, 1989). It could be argued that in many cemetery sites the only real distinctions are between the individuals buried with grave goods and those without. However, to simply divide populations into two such broad categories would be an oversimplification, and would not take into account the presence of distinctive artefacts with some burials and not others.

The question of whether status was acquired through actions during life or was inherited or primarily defined by factors such as age or sex/gender, as discussed above, is still open for debate, in Early Medieval England, and in may other archaeological populations (Lillios, 1999, Stoodley, 2000). The fact that the graves of infants and children sometimes contained artefacts, including items such as weapons that the child could not have used (Härke, 1990), supports the hypothesis that, for some children at least, status was inherited. Legal documentation also sheds light upon this; the children of a "mixed marriage" between a slave and bondman/bondwoman took the status of the mother, whether this was bonded or free (Codex Justinianus XI 48 xxi (Cave and Coulson, 1965)), although the influence of this late Roman legislation upon Early Medieval England may have been limited (Wormald, 1999).

In all the methods used to define social groupings it is assumed that individuals buried without grave goods were of the lowest social status, but while this may be the case in some cemeteries, particularly those from the earlier phase of the Early Medieval period, it may not be true of all sites, especially those that are later in date. Furthermore, differential preservation of artefacts may prevent us from seeing the full picture of burial practice. Leather, wood and textiles are only rarely preserved in Early Medieval burials, but there is occasional evidence for the presence of these materials with some burials. Metal vessel repairs are found with some burials, indicating the presence of wooden or leather vessels (Drinkall and Foreman, 1998), and fragments of mineralised fabric, horn and leather have been found on metal artefacts (Walton, 1992). It is possible that perishable objects that held great social significance may have accompanied individuals who appear to have been buried without grave goods. Rich garments made from silk or other exotic materials, a finely carved wooden box or an expertly crafted leather bag, could all indicate wealth and social standing, but leave little or no trace in the grave. Other items used to display the social standing of the buried individual may not have ended up in the grave, but instead may have been consumed at the funeral or taken away by the mourners (Ucko, 1969).

The availability of objects and materials may also affect their value (Arnold, 1997); in regions where materials such as amber or amethyst are readily available, beads made from these materials may be of less value than in regions where these materials have to be imported, and hence require a greater expenditure of energy to obtain (Tainter, 1977). As Hedeager has shown, the availability of artefacts for inclusion in burial may be controlled by the highest status groups in society, particularly artefacts that are non-local (Hedeager, 1992), so it is likely that the presence of imported items will indicate individuals of higher social rank. Therefore, the location of a cemetery and the resources in the region probably has a bearing upon the relative social values of the artefacts found there, and it may be impossible to develop systems of interpreting the relative status of burial assemblages that are applicable to more than one region, or even more than one cemetery site.

There are variations within gendered burials in the types and number of artefacts included in the burials; one individual at Norton Mill Lane was buried with a spear and two potsherds while another had a spear, shield and seax (Sherlock and Welch, 1992). While both of these burials would fall into the category of "weapon burials" they are clearly different, and it is possible that this difference is due to the use of the burial rite to display variation in social identity. The presence of a spear may indicate one facet of identity such as the role as a warrior, or the badge of a certain rank, while the variation in the other types of artefacts may reflect different aspects of identity. Some cemeteries may have served more than one community, and in these cases the variation in burial practices may represent competition and social display between the communities (Steuer, 1989); by choosing to include different items in burial they may have been emphasising social or ethnic distinctions between the communities (Halsall, 1995b, Ucko, 1969).

It is also vital to remember that the burial rite as seen archaeologically represents the actions of the living, rather than the specific wishes of the dead (Steuer, 1989, Williams, 2005). The burial rite as proscribed or intended may be altered as a result of local traditions (differences in dress styles, variation in the meaning or availability of various objects) or local conditions (soil types, weather, pre-existing monuments or burials within a cemetery, availability of individuals and resources to carry out a burial). A wide variety of factors might influence the manner in which a burial was carried out, some of which might be related to social standing and roles within society, and others that might be purely coincidental. The season and weather at the time the burial was carried out could influence the location, size and depth of the grave; if the ground is frozen or waterlogged, it can be extremely difficult to dig the soil and hence graves dug in winter may be smaller and more shallow than those excavated in warmer weather. In these cases analysis of relative grave depth as evidence for status in energy expenditure models may be affected.

2.1.4: Burial Practice and Religion

In late-Roman Britain, both Christianity and non-Christian religions were practiced, but Christianity was not the dominant practice until the late 7th century AD (Geake, 2002, Hines, 1997). The major assumption about the Early Medieval practice of burying the dead with grave goods is that it is a "pagan" custom, and that Christians did not bury their dead with any artefacts. Inhumation of the body is a practice that is prevalent in both Christian and non-Christian societies, and the concept that burial with grave goods is non-Christian is somewhat questionable. There is nothing inherently non-Christian about burial of an individual in their clothes, and it can be argued that items such as jewellery, personal knives and even weapons are a part of an individual's daily dress. Interestingly, some of the most lavishly accompanied burials on the Continent are those of aristocratic individuals buried beneath Cologne Cathedral and the abbey church of St Denis (Halsall, 1995a, James, 2001), where the location of burial strongly suggests Christian beliefs. It has been suggested that the need to express the rank of the individual and their family through burial was greater than any need to follow defined Christian practices (Steuer, 1989).

There are several other misconceptions relating to practices of Christian and non-Christian or "pagan" burial practices in the Early Medieval period. Some of the most widespread of these are that Christians are always buried in an East-West orientation, while pagans practiced North-South burial and that Christians were buried in a supine position while pagans were buried in a variety of positions. Although it would be convenient if these statements were true, unfortunately the belief systems and burial practices of Early Medieval people do not appear to have been so clear-cut. As mentioned above, the practice of north-south orientation is more common in the North-East than in other parts of the country, and as Christianity was a strong influence in this region from a relatively early date the possibility that the individuals buried in this orientation cannot be dismissed. It may have been simply the case that the local tradition of north-south burial was a stronger influence than Christian east-west burial.

It has already been mentioned that, even in cemeteries dating from the 5^{th} and 6^{th} centuries, some individuals were buried without grave goods. Does this mean that these individuals were Christian? Although the possibility cannot be entirely dismissed, in most cases it is unlikely, as Christianity did not become well established in England until the 7^{th} century AD. Conversely, individuals buried with grave goods or personal items in an apparently Christian cemetery are not necessarily pagans. The bible does not legislate on whether a burial may or may not include grave goods, and the Church did not set out strict guidelines for burial practices (Thompson, 2002) until it was well established, some 400 years after Christianity was first introduced to England (Taylor, 2001). Recent excavations have produced evidence for richly accompanied burials dating from the mid 7^{th} century AD with clearly Christian artefacts, such as the "royal" burial at Prittlewell, Southend and Bloodmoor Hill, Lowestoft, where a burial was found in an Early Christian cemetery with a pendant cross necklace (Sam Lucy *pers. comm.*). Restrictions upon activities such as sacrificing to devils, eating food offered as a sacrifice and burning grain for the dead were forbidden by the late 7^{th} century, and the ban against eating and drinking in the "place where the corpse lies" was reinforced in the late 990's (Taylor 2001, pp 141). The fact that the Church had to rule against these practices implies that they were still taking place. There is also evidence for the "Christianisation" of pagan practices; some grave goods were decorated with Christian symbols, and baptismal spoons and crosses are found in some conversion-period burials (Hines, 1997); and even saints were sometimes buried fully dressed and accompanied by grave goods, as was the case with St Cuthbert (Geake, 2002).

The specific location of a burial within the cemetery could be indicative of variation in social status. In graveyards regulated by the Church, on the Continent at least, individuals who committed suicide were not permitted burial amongst other Christians, nor were thieves, while high status individuals were buried in the most desirable plots near to the church, or in non-church cemeteries, the earlier burial of a "founder" (Effros, 1997). In Christian cemeteries the northern part of the cemetery may be reserved for the poor and low status individuals- "customarily the northern parts which were not within the sun's 'genial influence within whose rays no imp or fairy, demon or ill, or spectre pale can haunt the silent graves' (Gomme 1887: 205-6, quoted in Ucko 1969, pp 267). This apparently Christian practice seems rather pagan in essence, and as such may have its origins in earlier practice.

Cemeteries that span a later date, such as the Bowl Hole at Bamburgh and Norton Bishopsmill, are more likely to have been Christian, but even at these later sites there is variation in the types of burial practices carried out. While the majority of these later graves are in a roughly east-west alignment, some contain artefacts such as knives and pins, stones, or charcoal and others have stone or wooden linings, and in some cases coffins or boxes (Geake, 1992, Thompson, 2002). The meanings of these artefacts and structures are even less clear than the grave goods found at the earlier sites, but the presence of this variation does suggest that meaning was still associated with the burial rite.

It has been suggested that the decline in the practice of furnished burial may be associated with a decline in the significance of gender in the construction of social status, and an increase in the importance of other factors such as rank and wealth (Geake, 1992), and an increase in the importance of the Church (Boddington, 1992). This ties in well with the fact that the grave goods found at later cemeteries such as Bamburgh are predominantly "gender-less" items such as knives, buckles and pins. In these later sites personal objects may have been too valuable, in terms of actual wealth or in social terms, to the living to be disposed of with the dead. An increase in the significance of kinship in the formation of an individual's social status might lead to a greater desire to hold onto the belongings of one's ancestors (Geake, 1997), to maintain a link between the status of the living and the status of the dead. Evidence from wills dating from the 10th century suggests that wealth and property was distributed amongst family, kin and the Church in order to strengthen family connections, and political associations (Wareham, 2001). This suggests that the arena for expression of social status shifted away from the burial ground and towards the Church or the local political system (the two of which may well have been closely interlinked). If status was primarily acquired during the 5th to 7th centuries, and not passed down to the descendents, an individual's status would have died with them, hence the need to bury them with the artefacts that represented this status. However, once a system of inheritance of status had developed in the later 7th and 8th centuries (Stenton, 1971), those artefacts gain a different meaning, representative of the inherited status, and thus become too significant to the living to be buried with the dead.

The presence of other items in later burials may be indicative of religious practices; charcoal or clay in and over the grave and the presence of pillow stones and stones over the body may be representative of the individual's role in life as a penitent, or that they died in a state of sin, and hence must perform penitence in death (Thompson, 2002, Thompson, 2004). The increase in coffined burial, and burial in chests in this period may also indicate a reduction of the significance of the dead person as an individual, as a coffin prevents the body from being seen by the mourners. The status of the individual may instead be displayed above ground, with gravestones, monuments or structures above the grave (Thompson, 2004 pp 118).

2.1.5: Status and Physical Activity

Evidence for occupation, labour and other physical activity in the Early Medieval period is plentiful, both from textual and archaeological sources. Some of the activities that the different social ranks in Early Medieval society undertook have been mentioned already; the *gesith* may have been involved in hunting and warfare when necessary, and the task of the female grinding slave as mentioned was probably more strenuous and less rewarding. Although there is no definition of the role of the grinding slave in the law codes of Æthelberht (see above), it seems plausible that she was involved in grinding grain. Warfare was a matter for the aristocracy, and peasants do not seem to have been expected to take part in the fighting, but were employed to act as porters and to distribute supplies (Rollason, 2003 pp 184-5). Aside from the evidence for activities such as spinning and weaving, and the use of weapons, all provided by the burial assemblages, archaeological and literary evidence for a wide variety of tasks and occupations exists. The agricultural tasks of ploughing, sowing, harrowing and reaping are mentioned by Bede, although he seems to have been rather more interested in other activities such as glass blowing, cement mixing and lathe-working (Fowler, 1997). Many of the charming and vibrant illustrations in Early Medieval manuscripts such as the "Julius Work Calendar" (Cotton MS Julius A.VI) show men involved in a range of seasonal activities; pruning vines, ploughing with oxen, digging, sowing, harrowing, tending sheep, cutting wood, reaping and gathering crops, hunting and threshing. Women are seldom included in manuscript illustrations; this may be more a reflection of the monastic origins of these documents than an indication of a sexual division of labour.

The illustration of a ploughman with his pair of oxen from the Harley MS 603, fol 66r, dating from around AD 1000 is strikingly similar to the bronze model of a ploughman and ox pair, dating from around AD 100, and found at Piercebridge, Co Durham, suggesting a continuity of the methods of agriculture throughout the first Century AD (Fowler, 2002). Both ploughmen are bending over the plough or ard, encouraging the oxen with a stick, and the force required to steady the plough is shown in the bend of the leading leg. Clearly, ploughing was hard work, a sentiment echoed by the ploughman in Aelfric's *Colloquy*, a teaching text dating from the end of the tenth century AD in the form of a conversation between a master and his pupils. The ploughman "must plough a full acre or more every day", "fill the oxen's bins with hay, and water them, and carry their muck outside" onerous tasks which are made worse by fear of his master and the fact that he is bound to service; "It's hard work, sir, because I am not free" (from Aelfric's *Colloquy*, quoted in Fowler, 2002, pp 192-3). Ploughing involves both arms, places stress on the back and requires strong legs to push the plough through the soil, and this essential activity was almost certainly carried out at all four of the sites under examination in this study. The occupations mentioned in Aelfric's Colloquy; including ploughman, baker, oxherd, shepherd, huntsman, merchant and shoe-maker show that, by the tenth century AD, some individuals were specialising in certain activities. However, other than the hint of specialism offered by the weapon burials, burial practices give little indication of any specialised occupations undertaken in life.

There is also documentary evidence for specialisation of labour. In AD 758 Abbot Cuthbert of Durham wrote to the Archbishop of Mainz to request a glassmaker to be sent to him, to teach the craft to his men (Cave and Coulson, 1965), and the stone crosses and other sculptures in Northumbria are evidence of highly skilled craftsmen (Higham, 1993). The Franks Casket is also both evidence of a skilled worker and provides images of the legendary smith, Wayland (Rollason, 2003). There is also evidence for the specialisation of the smith in documentary sources; the laws of Ine state that "if a nobleman moves his residence he may take with him his reeve, his smith and his children's nurse" (Ine 63 (Attenborough, 1922)). In addition to defining the smith as a specialist, this law code also gives a rare indication of another of the types of work carried out by women. One of the tasks most commonly associated with women in Early Medieval England is weaving, which is identified by the presence of spindle whorls in female graves (see above), but this was also a task for women in a monastic context. Bede reports that at the monastery of Coldingham the nuns were weaving clothes "fit for brides" for themselves to wear [Bede Ecclesiastical History 4: 25 (23) in Rollason, 2003 pp 182-3). While Bede makes this remark to highlight the extent of vanity in the Church, in doing so he also highlights the fact that clothing was generally produced on a local scale.

Documentary sources dating from the years before the Norman Conquest describe the duties of freemen, peasants and other sub-ordinates carried out for the lord of the manor. The free man was expected to act as an escort for visitors, to ride and carry goods, to take part in the harvesting, to act as a guard, maintain hedges and build fences. The individuals of the next rank down, the "cottager" who worked the land, but was still free and expected to pay his dues to the Church. Below the cottagers were the *geburas*, who held a small amount of land and were expected in return to work for the lord for two days a week for most of the year and three days a week at harvest and between Candlemas and Easter, and to plough up to 8 acres of land for his lord in return for pasture rights and as rent (Stenton, 1971). While the status of the free man and the *geburas* was clearly different, some of the tasks that they were expected to undertake were the same, particularly in the busy harvest season. However, it seems that the physically demanding but skilled task of ploughing was reserved for those of the lower social ranks. Despite the evidence for a variety of physical activities, some of which may have been reserved for individuals of a certain social status, it must be borne in mind that we cannot be certain of when individuals began to undertake these activities, to what extent individuals specialised in certain occupations, and how this may have impacted upon any changes seen in their skeletal remains (Jurmain, 1999). It is unlikely that skeletal material from the Early Medieval period will provide evidence for specific activities, but may indicate general differences in the level of activity undertaken by different groups within society.

2.2: Summary

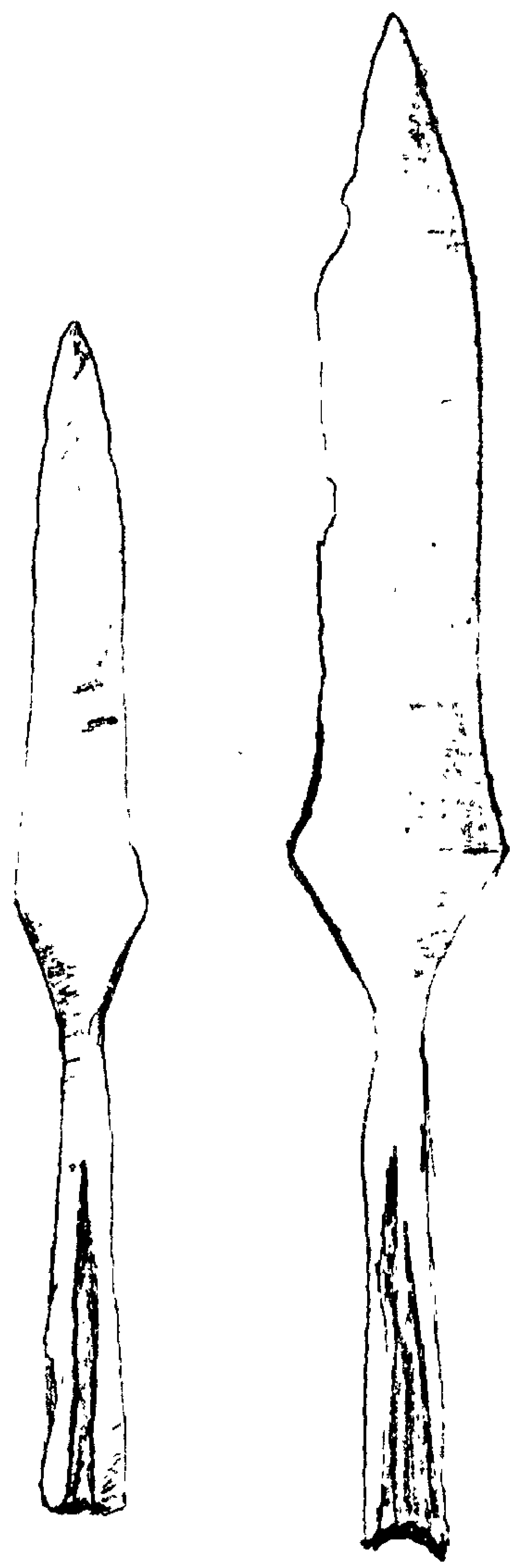
Clearly, the inference of social status from grave goods is not a simple process, but if the differences in burial practices seen in Early Medieval cemeteries are indicative of differences in social identity, the opportunity then exists for research to reveal more about the lives of Early Medieval people. Social status cannot be simply "read off" the burial assemblage, but the manner in which the living chose to bury the dead can shed light on the aspects of that individual which the living felt was most in need of emphasis (Lucy, 2002a).

While it may not be possible to directly link the legal ranks recorded in the textual sources to the variations in burial assemblages seen in Early Medieval cemeteries, it may be possible to identify relative differences in social status, based upon the types and quantities of artefacts included in burials, and other factors such as the amount of energy expended in preparing the grave and the individual. There are clearly a great many issues with the systems used to differentiate groups in cemetery samples based upon grave goods and burial practices and it is unlikely that a single system can be developed that will be suitable for all Early Medieval cemeteries. Therefore it is important to take a regional approach, and where possible, restrict the chronological range of the samples under study.

Variations in social status and rank may influence the lifestyle and level of work that an individual had to undertake, together with access to a good diet and healthcare, factors that may in turn have an impact upon the skeleton. Thus the combination of evidence from human remains and the artefacts and structures with which they were buried may be able to shed more light upon the lifestyle of these individuals. It is apparent that Early Medieval society was ranked, and social mobility was possible, suggesting that with hard work and/or skill an individual could have been able to improve their social standing. In a society where social status was flexible and could change during the lifetime of the individual it may have been particularly important for the individuals who had changed their status during life to emphasise this status at death, through burial practices, which in turn served to display the status of the family, or whoever was performing the burial. Therefore, if social status was acquired through specialism or physical work, this may be reflected in the patterns of MSM in individuals buried with different types of artefacts. Conversely, if status was inherited, or based upon factors other than physical ability, the individuals with the highest status burial practices might be expected to show the lowest levels of skeletal changes associated with physical activity.

The following Chapter will discuss the selection of the skeletal samples used in this study, and describe the methods used to identify age, sex and social status. The methods of identifying and recording markers of activity related stress in the skeletal material are also discussed.

Chapter Three: Materials and Methods



3: Materials and Methods

The Early Medieval period in England was culturally diverse, as demonstrated by the variation seen both in the archaeological and textual evidence (Carver, 1994), and this diversity is both regional and chronological. While the paucity of radiocarbon dates from many cemetery sites makes it difficult to control for chronological variation within and between sites, regional variation can be controlled for by the selection of samples from one area, in this case the North-East of England.

3.1: Materials

Well-preserved and well-excavated Early Medieval cemeteries are not common in the North East of England. In Meaney's "A Gazetteer of Early Anglo-Saxon Burial Sites" (1964), eleven sites in Northumberland are recorded as having inhumation burials present; 71 sites are listed for Lincolnshire, seven sites are listed in County Durham, and 83 sites with inhumation burials believed to be Early Medieval in date are listed for Yorkshire (Meaney, 1964). However, of these 172 sites only 43 are reported as being primarily inhumation cemeteries rather than small numbers of inhumations in primarily cremation cemeteries, and many of these inhumation cemeteries have fewer than 50 individuals. More recently, work by Lucy has produced an updated gazetteer of cemetery sites in East Yorkshire (Lucy, 1998), but at present there is no fully up to date record of all the inhumation sites excavated in the North East of England. As new burials are discovered frequently, it would be a considerable task to produce such a resource, but one that would be of great benefit to archaeological research in the region.

Many of the sites listed by Meaney were discovered during the 19th and early 20th centuries, often discovered during development work (James, 2001), poorly excavated and in most cases few records were made of the material excavated. For the majority of these sites the skeletal material is no longer available for study as it was often not retained. Of the sites listed for Northumberland, the excavations at Yeavering produced little skeletal material besides teeth, and the location of any surviving material from the other sites, aside from

Bamburgh, is unknown. Although some large cemeteries have been identified and excavated in a more systematic manner, such as that at Yeavering, where several hundred graves were excavated in two cemeteries (Hope-Taylor, 1977), the soil chemistry in this region does not generally lead to good preservation of skeletal material. At Yeavering the only human skeletal material that survived to excavation was tooth crowns and fragments of bone. Many of the other sites excavated only identified small numbers of burials (Higham, 1993). Consequently the number of large skeletal samples from sites in this region that are suitable for this type of study is limited. Furthermore, there has long been a bias in research towards the Early Medieval archaeology of the South and East of England (Lucy and Reynolds, 2002), and only recently have researchers begun to re-examine the archaeology of the North. Hopefully this study will bring attention to some of the recently excavated cemetery sites from the North East, and the potential for research that exists in this region.

3.1.1: Selection of the Skeletal Samples

Firstly, it was necessary to identify sites which had been excavated using modern techniques and that were either fully published, or the site archives available for study. Techniques of excavation and recording have changed dramatically since the discovery of many Early Medieval sites (Lucy, 2002), and in many early excavations human skeletal material was not considered to be as valuable a source of information as the associated material culture such as grave goods, and was frequently not retained for study. The four sites included in this study were selected on the basis that over 50 individuals were excavated, in order for the final sample to be of sufficient size to allow statistical analysis. Figure 3.3.1a shows the location of the sites selected for analysis.

The state of preservation of the skeletal material was also an important factor for inclusion in the study- in order to identify the conditions that may have arisen as the result of physical activity (discussed below) it is necessary for the majority of the skeleton to be present, bones to be relatively complete and for the condition of the bone to be good. Good preservation of the skeletal material is also essential for the identification of sex and age, variables that were essential for the interpretation of the data.

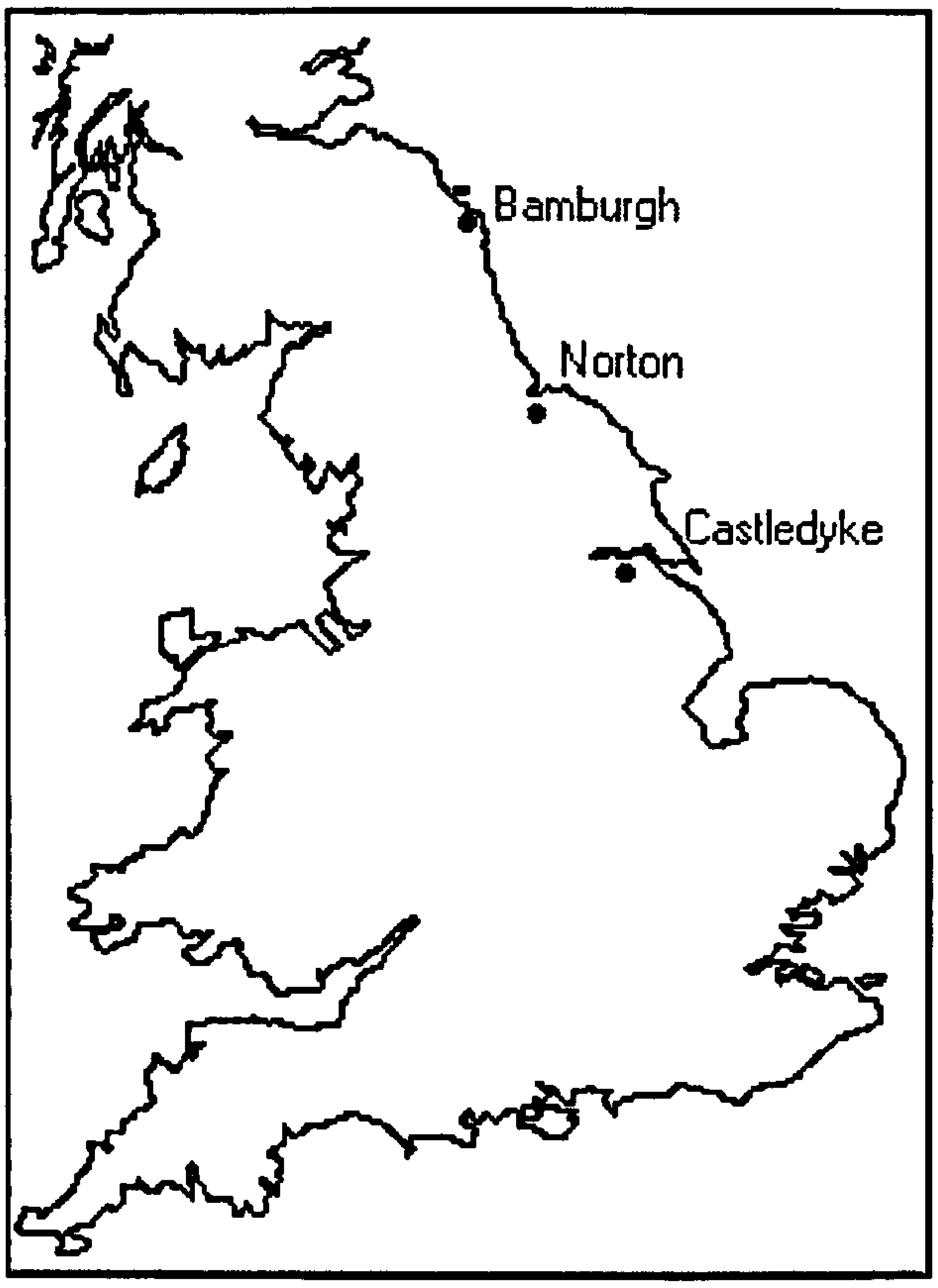


Figure 3.1.1a: Map showing the location of the Bowl Hole cemetery at Bamburgh, the Norton Mill Lane and Norton Bishopsmill cemeteries, and the cemetery at Castledyke South, Barton on Humber.

The specific sites chosen for study represent different kinds of settlement- the royal fortress site of Bamburgh, the probable farming communities at Norton Mill Lane and Norton Bishopsmill, and the possible port in the area of Castledyke South. By examining populations from sites of varying types it was considered possible to identify different patterns of activity between settlements with varying functions. At all four of these sites there were differences in burial practice that may indicate social differentiation, and hence the potential exists to examine the relationships between markers of activity related stress and social status at these sites.

The four sites represent a range in date from the 5th to the 9th centuries AD, offering the opportunity to examine changes in activity patterns over time, between the sites. As discussed in Chapter 2, has been suggested that during this period the social structure of Early Medieval England developed and changed, particularly in the ways in which status was acquired and recognised (Brenan, 1991). It is likely that the changes seen in burial practices during this period reflect the changes in social identity, which may in turn have led to differences in lifestyle and physical activity. The skeletal samples from Bamburgh and Norton Bishopsmill were both in use later than Castledyke and Norton Mill Lane, and hence any differences in the patterns of skeletal change between these sites may reflect changes in social identity over time.

Following the selection of the cemetery sites is was necessary to identify the individuals within the sample that were suitable for study. Suitability was based upon the level of preservation of the skeleton and the biological age at death. As detailed below, only adult individuals were selected for inclusion. For the purposes of this study adulthood was defined as those individuals over the age of 17 years, as identified by the state of fusion of the epiphyses that represent the final stages of skeletal maturation (the iliac crest, medial clavicle and the ventral rings of the vertebrae) and tooth eruption (third molars, where present) (Bass, 1995, Cox, 2000, White, 2000). Wherever possible, a combination of methods of ageing was used. It must be observed however, that, as discussed in Chapter 2, the social definition of adulthood in Early Medieval populations may have been at a much younger age (Gowland, 2002). At present it is unknown at which point children fully took on adult status and tasks in Early Medieval England; consequently it seems unwise to assign an arbitrary age of adulthood to individuals who may not yet be performing adult tasks, and who may not have had time to develop skeletal changes as a result of physical activity. In order to examine the influence of status, age and gender groups it is necessary to be able to assign age at death and biological sex to each individual, and therefore juveniles were excluded from the study. Although activity related changes have been identified in clinical studies of juveniles (Adams, 1965), without analysis of DNA it is not possible to reliably assign biological sex to juvenile skeletal remains. Analysis of morphological variation in juveniles is not accepted as a sufficiently accurate method (Brown, 2000).

Adult individuals that were too poorly preserved to obtain both age and sex data were excluded from the study, as these individuals generally did not have a suitable level of preservation for other data to be collected. A suitable level of preservation was defined as the presence of the majority of the limb bones and joint surfaces and/or the presence of a relatively complete vertebral column. Where age and sex could not be assigned due to ambiguity or poor preservation of the relevant elements, the individuals were recorded as "adult" and "sex unknown". Where possible, as in the cases of Norton Mill Lane and Castledyke South, the published site reports were consulted to identify the individuals suitable for study in advance of recording the sample. However, to prevent any biasing of the analysis, the assessment of age and sex for each individual was performed without reference to the skeletal report or grave assemblage.

The following sections will describe the sites and skeletal samples examined in this study and the systems used to rank the burials from each of the sites. Comprehensive published site reports are available for Castledyke South (Drinkall and Foreman, 1998) and Norton Mill Lane (Sherlock and Welch, 1992), and the site report for Norton Bishopsmill is in press (Annis and Anderson). At present there is no site report is available for the Bowl Hole, Bamburgh, so this site is discussed in more depth.

Although the samples in this study all come from the North East of England, it is likely that there was some degree of variation in the availability of materials and social meanings of the objects included in the burials. Temporal differences between the samples are also likely to affect the choices of artefacts placed in the grave and their social implications (Lucy and Reynolds, 2002). As discussed in Chapter 2, there are no widely accepted methods of analysing social status from grave goods, as there can be a great deal of variation between the assemblages seen at different sites, even when the sites date from the same time period. Various computer programs have been developed to rank the assemblages discovered in graves (Brenan, 1998, Hirst, 1985), but these programs are complex and not capable of dividing samples into specific groups. Therefore, for this study a simple assessment of the number and quality of grave goods associated with each individual, and variations in burial practice was considered to be most appropriate. The variation in the types of artefacts associated with burials at the four sites meant that it was not appropriate to attempt to apply the same methods of "scoring" burial assemblages between all four sites. It was necessary to examine the apparent wealth and significance of collections of objects on an individual basis; at Norton Mill Lane and Castledyke South there were many individuals buried with grave goods, and a great deal of variation in the type and quality of the artefacts. At Norton Bishopsmill and Bamburgh fewer individuals were buried with artefacts, and the types of objects included in the burials were different to those seen from the two earlier sites. Therefore the social "value" of a knife at Bamburgh, where few individuals were buried with knives was probably different to the "value" of a knife at Castledyke, where knives were more commonly found in the graves. An object that is rare and unusual, and hence of high social value at one site may be more commonplace at another, and therefore carry less weight in a system of scoring (Tainter, 1977). The social "value" of objects may have been related to the ease of procurement of the object (as with stone axes in the Neolithic) or how the object was obtained, i.e. as a gift from a distinguished person on an heirloom passed down a family (Lucy 2000, pp 173), as much as the material value or usefulness of the object itself (Halsall, 1995).

The data concerning the grave goods and burial practices for each individual were taken from the published site reports. In the cases where these were not available such as Norton Bishopsmill and Bamburgh, the information was collected from the context sheets and interim reports. As the methodology used to identify status groups at each site is different, the specific methods used will be discussed in the following section. In all cases, the information relating to the burial practices and grave goods associated with each individual skeleton were not examined prior to the osteological analysis, to prevent the possibility that knowledge of the status group of the individual would influence the analysis of the skeletal material. Furthermore, artefact groups were assigned to individuals without reference to the sex of the individual, and sex was not a requirement for inclusion in any of the artefact groups.

3.1.2: Castledyke South, Barton-on-Humber, Humberside

The cemetery site at Castledyke South was first identified in 1939, when five graves were uncovered during the construction of air-raid shelters at the Elswick Hopper Bicycle Factory, Barton-on-Humber. Between 1975 and 1990, partial excavations of the cemetery took place, identifying 196 graves containing the remains of 227 individuals. It is thought that this sample represents around 50% of the whole cemetery population, possibly representing a community of 40-60 individuals alive at any one time, or around 4-6 families, and appears to be the largest known inhumation cemetery in Lindsey. The typology of grave goods suggests that the cemetery was in use from the late 5th or early 6th centuries to the late 7th century AD. A published report is available for this site which includes detailed analysis of the skeletal material and grave goods (Drinkall and Foreman, 1998).

The site lies at the southern edge of the Medieval town of Barton-on-Humber, in a position that would have allowed a view of the Humber estuary prior to the development of the modern town. During the Early Medieval period the River Humber formed the main territorial boundary between the kingdom of Northumbria and the kingdoms to the south. During the period of use of the cemetery, Barton-on-Humber was within the Kingdom of Lindsey, but the region had very strong links with Northumbria, as is attested by the presence of very similar objects in burials in the two regions (Leahy, 1998b). It is thought that the ditches and banks identified at the cemetery site represent the remains of a prehistoric earthwork, within which the cemetery was purposefully situated, using the eastern beaded ditch as a boundary (Foreman, 1998a). Considering the nature of the ditch, which was interrupted and apparently constructed in phases, it is possible that the earthwork was a Neolithic causewayed enclosure or henge monument. The population who buried their dead at Castledyke may have used this site as a means of identifying their dead with the 'ancestors' of the region and signifying the ownership of the landscape, a practice that was common in Prehistoric Britain, and is frequently seen in other Early Medieval cemeteries (Lucy, 2002).

There is evidence for a possible Early Medieval settlement around 400m to the North-East of the cemetery site; excavations at St Peter's Church identified earlier buildings associated with pottery dating from the 5th to 6th centuries AD. The association of animal bones with these structures suggests that they were domestic rather than early church buildings, as does the discovery of late 7th century domestic pottery in the grounds of the vicarage (Leahy, 1998b). Furthermore, there is artefactual evidence for two other cemetery sites in the area of Barton, suggesting that this area was important in the Early Medieval period (*ibid*).

Many of the burials at Castledyke included grave goods, the location of which suggests that the individuals were buried fully clothed. The grave goods suggest that this was not a particularly rich site, but, as was also seen at Norton Mill Lane, there were some apparently more wealthy individuals within the population. In comparison with other cemeteries in the immediate area, Castledyke had the lowest percentage of individuals buried with manufactured objects, which may reflect the long lifetime of use of the cemetery as the inclusion of grave goods became less frequent in the 7th century AD (Leahy, 1998a). Objects were imported from elsewhere in Britain and from Europe, indicating that the community was involved in trade, a hypothesis that is supported by the location of the site near to the port town of Barton-on-Humber. A range of burial types were found in the cemetery including individuals buried in coffins or with coverings for the body, structures or mounds marking the burials, a range of burial positions and a variety or orientations. Although the soil conditions at the side precluded the preservation of organic material, a total of 23 burials had features in the grave that suggested the presence of coffins or covers. Twenty-five graves had evidence for post-holes, suggesting the presence of grave markers or structures. The depth of the burials varied, ranging from very shallow, only a few centimetres in depth, to over 0.6 m deep, although there was very little variation in the average depth between individuals buried with artefacts and those without (mean depth without grave goods – 0.23 m, mean depth with grave goods – 0.24 m).

In certain areas of the cemetery the density of burial was greater than in others, perhaps as the result of intentionally close placement of burials in family plots. In the northern and southern regions of the cemetery the burials were particularly crowded, and many of the burials are orientated in respect to the earliest burials in the area. This practice may represent continuation of family traditions, or perhaps social or political groupings (Leahy, 1998a). Burial practice showed a correlation with the age and sex of the individual, and consistent levels of social stratification appear to have been present throughout the lifetime of the cemetery.

The cemetery at Castledyke is unusual for the long duration and intensity of use and the large number of individuals excavated. There is evidence for phasing of use at the site, although the graves that are dated to the 5th and 6th centuries, and those dated to the 7th century are distributed across the site, and do not really show any clustering in any particular area of the site (Drinkall, 1998). This apparent lack of clustering may suggest that different family or kin groups used different areas of the cemetery at the same time. There is also apparently no association between "higher" status graves and either of the phases, with the apparently high status burials being present in both Phase 2A and Phase 2B, suggesting a large degree of continuity of burial practice across the phases (Brenan, 1998). Therefore it is probably reasonable to pool both phases together, for the purposes of examining variation in social status across the whole cemetery.

The location of the cemetery site near to the border between Northumbria and Lindsey may have implications for both the expression of social status through burial practice and for the type and intensity of physical activity carried out by the individuals buried at the cemetery. The location of the cemetery near to a border may have led to a greater need to express social status, in a region that may have been less politically stable than other areas in the heart of an established kingdom. The location of Lindsey between the Kingdoms of Mercia and Northumbria, which were often in competition in the 7th century, may suggest that the region felt the effects of the warfare between its two neighbours (Leahy, 1998b).

Although there is no firm archaeological evidence for economic activities that might have taken place, the location of the cemetery may suggest some possibilities. The landscape around Barton-on-Humber is classified as good arable land, and has plenty of grazing for sheep and other livestock, and evidence from the Domesday Book suggests that large areas of land in Lindsey were utilised as grazing or hay meadows. Other industries such as salt extraction are also likely to have taken place in the area (Leahy, 1998b), and as Barton provides the first hard landing on the south bank of the Humber River it is probably that a port was present in this area (Leahy, 1998a). Unfortunately, the lack of detailed evidence for the settlement associated with the cemetery restricts the conclusions that can be drawn about the activities that the individuals buried at Castledyke may have undertaken during life.

Of the199 individuals that underwent osteological analysis, 46 were juveniles, 51 were male or possible male, 69 were female or possible female and 33 were adults who could not be sexed. Although there was an imbalance between the number of males and females identified at the site, this was similar to the inequalities seen at other Early Medieval sites (Boylston *et al.*, 1998). There was no spatial differentiation along the lines of age or sex within the cemetery, with males, females and children being found in all areas of the site. From the total skeletal sample 94 individuals were identified from the site report as being suitable for inclusion in this study. However, some of the skeletons were not available for study at the time the data collection was carried out, so consequently the sample used for this project consisted of 86 adult individuals.

Figure 3.1.2a shows a plan of the excavated area, with the grave cuts of the individuals examined in this study highlighted in colours indicating the artefact group into which each individual was placed. At Castledyke South, the burial assemblages ranged from no items or single small items, which may just have been in the soil at the time of burial, rather than placed intentionally as grave goods, to burials with many different items including beads, jewellery, dress fittings, weaponry, and pottery and wooden vessels. The individuals without grave goods, or with a single item were placed into Group 1. This group may represent the lowest status individuals in the society, but it is also possible that these individuals were buried without grave goods for another reason, possibly ideological or as a punishment. It is also possible that these individuals did have some grave goods that were made of wood, leather, cloth or bone, or other organic materials that did not survive in the soil at this site.

Of the individuals buried with grave goods there was further variation in the sets of objects; some individuals had two or three types of objects, such as brooches or a knife while the more complex assemblages included up to 16 different types of object, including beads, pairs of brooches, wrist-clasps, and silver jewellery items. Eight of the burials included a spear or seax, and these weapon burials were placed into a single group (Group 3), regardless of the other objects that were included in the burials. The other items included with the weapons in the Group 3 burials included knives, iron and copper buckles, animal bones and potsherds, but aside from a possible shield stud found in Grave 6, there is no real evidence for shields at Castledyke (Foreman, 1998b). There were no items of jewellery, brooches or beads in any of the burials with weapons. The burials with larger quantities of objects were placed into Group 4, where the artefacts included bead strings, brooches and exotic items such as an elephant ivory bag ring and beaver tooth amulet. It is most likely that the individuals in Groups 3 and 4 were the highest status members of the society. The following lists the artefact types that were present in each of the four artefact groups at Castledyke South:

Castledyke South Artefact Groups:

Group 1 - Single bead, small quantity of animal bone, single potsherd or no items

Group 2 - A knife, buckle, or one or more brooches, or one or more simple items

Group 3 - Weapon/s (spear and/or seax) and any other grave goods

Group 4 - Brooches, knives, personal items, pins, bead strings, girdlehangers and any other items

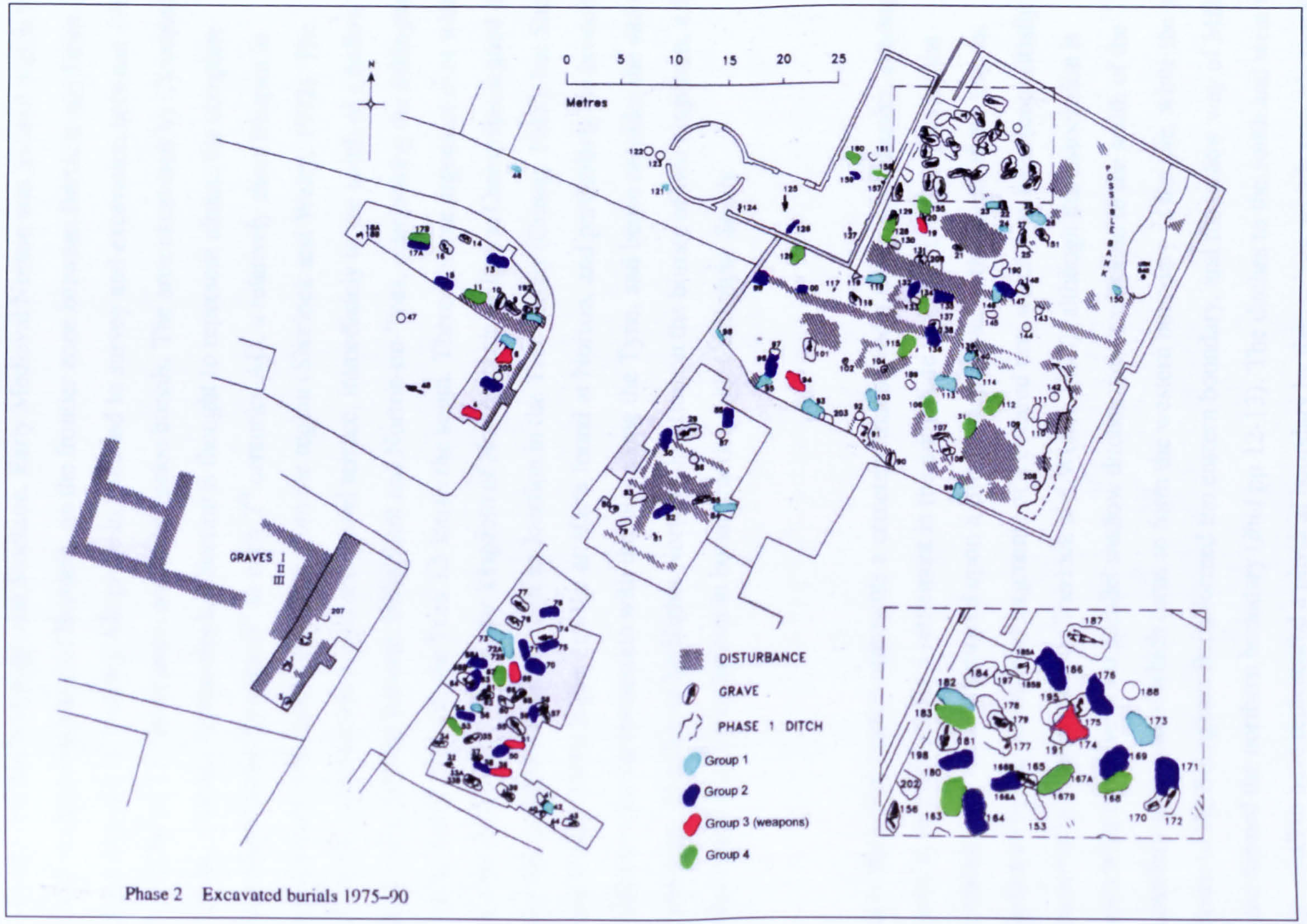


Figure 3.1.2a: Plan showing the skeletons excavated from Castledyke South. Coloured fill indicates the artefact group. After (Drinkall and Foreman, 1998) *pp 25.*

3.1.3: Norton Mill Lane, North Yorkshire

Norton is a small town in the North East of England that has now become part of the suburbs of Middlesbrough and Stockton. Early Medieval Norton was located within the Northumbrian kingdom of Bernicia, on the frontier zone between Bernicia and Deira. The discovery of a 6^{th} century AD grave in 1982 led to survey and excavation between 1983 and 1985 of 117 inhumation and 3 cremation burials. The area excavated by Cleveland County Council Archaeological Section is thought to represent almost the complete cemetery, dating from the 6^{th} to early 7^{th} centuries AD, a relatively short lifespan in comparison with other cemeteries from the region (Sherlock and Welch, 1992). The cemetery is located on a sand and gravel terrace, immediately to the south of a hollow way, Mill Lane, running between Billingham and Norton-on-Tees, overlooking the Billingham Beck, which runs into the Tees 3.5 km to the south. There is some argument over whether Norton Mill Lane falls into the kingdom of Northumbria or Deira; Cramp has argued that Norton is Deiran on the basis of its location in the Tees Valley (Cramp, 1988), but Sherlock and Welch (1992) argue that the artefacts found at Norton, and particularly the brooches indicate a strong connection with the sites along the Tyne, and hence consider the site to be Bernician. This debate highlights Norton's location on the border of two kingdoms, a factor which may lead to similarities in burial practice with Castledyke South.

It is likely that Norton represents a cemetery that served a farming community, although there is no evidence for a settlement in the immediate vicinity. It is possible that the cemetery was initially focussed upon a Bronze Age burial to the south of the site, as indicated by the presence of fragments of a collared urn, which may have been initially covered by a burial mound (Sherlock and Welch, 1992), although this association is somewhat tentative. Two parallel shallow ditches were excavated to the south of the cemetery area, one of which turns to form the western boundary of the site, while the slope down to the Billingham Beck formed the eastern boundary, and the hollow way of Mill lane formed the northern boundary (*ibid* pp 12-13). The ditches to the south and west were too small to have represented a physical boundary by themselves, so it is possible that they were symbolic, or served as the foundations of a fence around the cemetery. Soil cover at the site was shallow and several of the burials were disturbed by ploughing during the

Second World War, or by earlier use of the land. The nearest known comparable cemetery sites are at Saltburn, Darlington, and the recently excavated but chronologically later site of Norton Bishopsmill (discussed below).

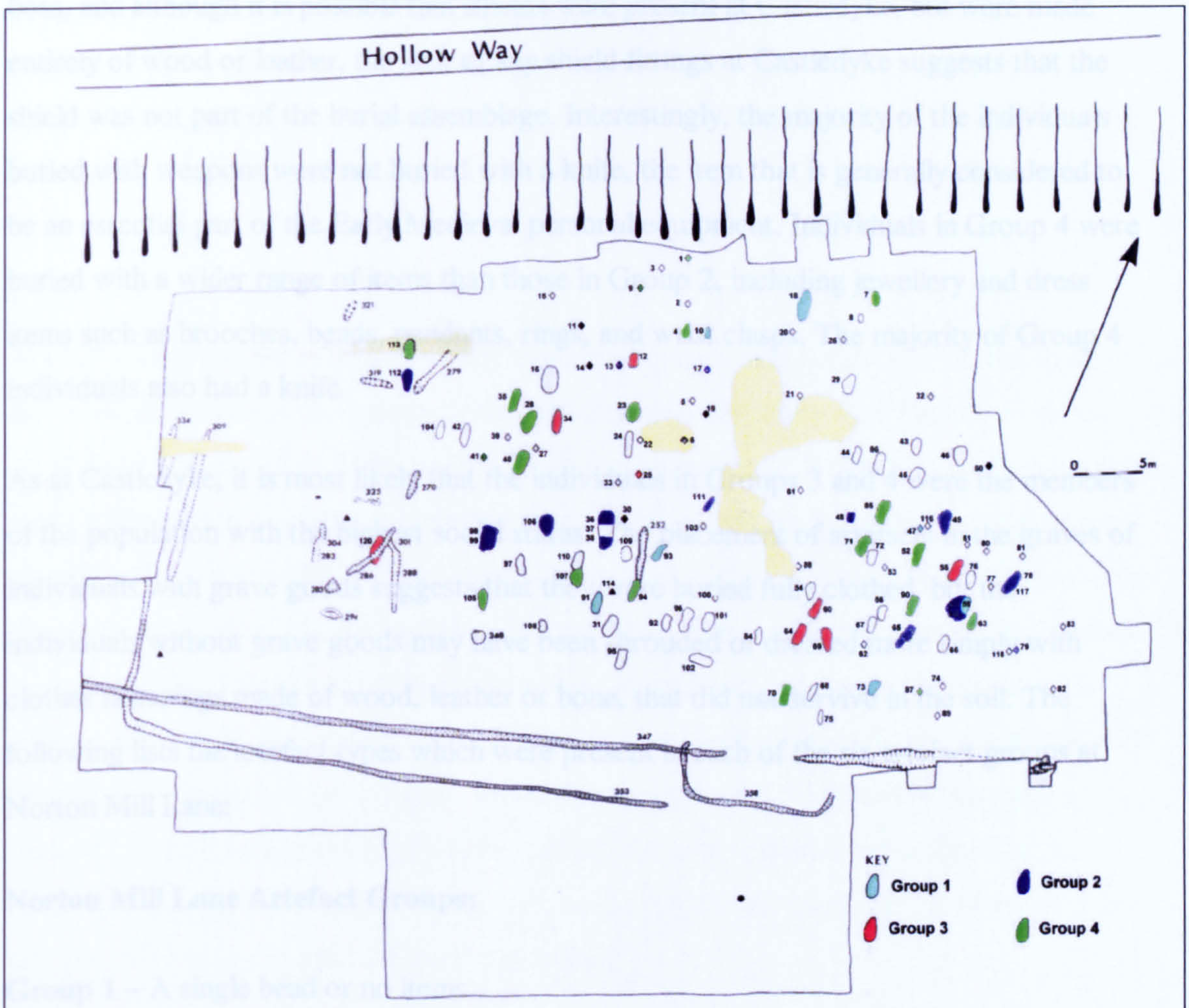
In contrast with Castledyke, the burials at Norton Mill Lane were arranged in rough rows rather than in plots or clusters and were generally orientated north-south, a pattern that was similar to that seen at Hob Hill in Saltburn, the nearest cemetery other than Bishopsmill. Two groups of burials have been identified at Mill Lane, divided by a north-south gap, which contained a disturbed hollow. Either side of this gap there was a difference in the orientation of the burials, with those to the east being more directly north-south in orientation than those to the west. Despite this difference, there did not seem to be any major distinction in the artefacts associated with burials in these two areas, with the exception of a group of graves in the north-east corner where some artefacts were found exclusively, including a Roman coin, small-long brooch and two iron girdle-hangers. Another distinct group of burials was seen in the north-west quadrant of the cemetery, this group was spatially distinct and may represent a family plot as both sexes, adults and children were all buried in this area (Sherlock and Welch, 1992). While the modern disturbance in the area cited by the excavators as the division between the two areas of the cemetery, together with the fact that this division does not extend the full length of the cemetery (see Figure 3.1.3a) casts some doubt over whether this was a real distinction, there does appear to have been some evidence of family or kin group plots in the cemetery.

The cemetery at Norton Mill Lane has a variety of burial positions and grave goods, although the frequency of crouched and north-south burials is greater than that seen in many more southern sites, possibly indicating a continuation of earlier burial practices (Higham, 1993). The quality and type of the grave goods suggests that the Norton population was not especially wealthy or "aristocratic", but the presence of weapons and ostentatious jewellery and personal equipment buried with some individuals indicates that there was social differentiation within the population. Some of the artefacts found at Norton were considered to be rare for the region, such as a pair of silver punch-decorated bracelets in Grave 40, a large saucer brooch from Grave 105, and the Frankish buckle set in Grave 22 (Sherlock and Welch, 1992). The presence of the Frankish items suggests either the presence of a high status individual with access to imported goods, or high quality Kentish copies (*ibid* pp 50), or that the female individual buried with these items was herself Frankish and had married into a local family. However the exotic and non-local items came to be buried at Mill Lane, their inclusion in some of the burials indicates the presence of a social elite with access to luxury goods (Peebles and Kus, 1977). In contrast with Castledyke, some of the weapon burials at Norton Mill Lane included shield bosses, indicating the presence of small buckler shields. This difference between the two sites may indicate symbolic differences in the expression of status, or it may be representative of actual differences in fighting style, which may in turn have an impact upon the patterns of changes seen in the skeletons of individuals buried with weapons at these two sites.

From the total of 117 inhumation burials, 51 adult individuals were selected for inclusion in the study, from a total of at least 126 individuals, including 87 adults. Of the adult individuals from the total excavated sample 51% were male and 49% were identified as female in the site report, suggesting that for the adults the sample was demographically normal. In comparison with Castledyke, the life expectancy for adults at Norton was relatively low, with only 6% dying after the age of 40 (Marlow, 1992). Thirty percent of the individuals excavated were juveniles, and the average age death was 9.4 years, relatively high in comparison with other Early Medieval samples, which may be due to the relatively low number of infants at Norton (Marlow, 1992). Although this may be an artefact of poor preservation, especially considering the level of disturbance and shallow burials at Norton, but it may also be an indication that very young children were buried elsewhere.

The prevalence of dental caries and abscesses was relatively low at Norton Mill Lane in comparison with other sites in the region, but rather higher than that seen at Pre-Conquest Jarrow, perhaps indicating differences in diet (Marlow, 1992 pp 117). There was little evidence for traumatic injury amongst the skeletons from Norton, with only two individuals showing lesions that might be associated with interpersonal violence (Birkett, 1992). Interestingly, both of these individuals were males buried with weapons.

Figure 3.1.3a shows the plan of the Mill Lane cemetery, with the individuals examined in this study coloured according to their artefact groups.



Norton cemetery plan showing excavated features

Figure 3.1.3a: Cemetery plan for Norton Mill Lane. Coloured fill indicates the artefact group, yellow areas indicate modern disturbance. Scale is 5 metres. After Sherlock and Welch (1992) pp 11.

The range of grave goods from Norton Mill lane was similar to that seen at Castledyke South, but there were some important differences. As a Castledyke, some individuals were buried without grave goods, or with an item that may have been residual in the soil or a modern intrusion into the grave fill; these individuals were placed into Group 1. Group 2 was the same as at Castledyke – individuals who were buried with a knife, and/or a small number of personal or dress items such as brooches, pins, a bone comb or buckle.

At Norton Mill Lane, some of the burials with weapons (Group 3) also included a shield boss, and although it is possible that shields were present at Castledyke, but were made entirely of wood or leather, the lack of any shield fittings at Castledyke suggests that the shield was not part of the burial assemblage. Interestingly, the majority of the individuals buried with weapons were not buried with a knife, the item that is generally considered to be an essential part of the Early Medieval personal equipment. Individuals in Group 4 were buried with a wider range of items than those in Group 2, including jewellery and dress items such as brooches, beads, pendants, rings, and wrist clasps. The majority of Group 4 individuals also had a knife.

As at Castledyke, it is most likely that the individuals in Groups 3 and 4 were the members of the population with the highest social status. The placement of artefacts in the graves of individuals with grave goods suggests that they were buried fully clothed, but the individuals without grave goods may have been shrouded or dressed more simply with clothes fastenings made of wood, leather or bone, that did not survive in the soil. The following lists the artefact types which were present in each of the six artefact groups at Norton Mill Lane:

Norton Mill Lane Artefact Groups:

Group 1 – A single bead or no items

Group 2 – A knife, with or without buckle or pin, one or more brooches or one or more simple dress items

Group 3 – A weapon or weapons (spear, shield and/or seax) and any other items

Group 4 – Several dress items: brooches, knifes, pins, personal items, jewellery and beads

3.1.4: The Bowl Hole Burial Ground, Bamburgh, Northumberland

Bamburgh is a small village on the Northumbrian coast, 50 miles north of Newcastle and 15 miles south of Berwick. The village is dominated by Bamburgh Castle, situated on a basalt outcrop overlooking the North Sea and the Farne Islands. In 1996 the Bamburgh Research Project (B.R.P) was established to explore the archaeology of Bamburgh Castle and the surrounding area. At present there is no published site report for the excavations at Bamburgh, although interim reports are in preparation.

In 1817 a storm uncovered a number of stone lined graves in the dune field to the south of the castle, these graves were described by Bateson as being "formed of flagstones set on edge" (1893, pp 56-7). In 1894 an excavation took place revealing several cist burials, two crouched burials and an infant. Unfortunately none of the early excavations produced any records and by the late 20th century the exact location of the cemetery had been lost. During the 1970s Brian Hope-Taylor undertook excavations to re-locate the cemetery, excavating along the ridge to the south of the castle and in the area that is now the Castle car park, without success (Hope-Taylor, 1962). It appears that Hope-Taylor did not consult the 1886 First Edition Ordinance Survey map, which clearly shows the "Old Danish Burying Ground" in the dunes to the south of the castle. This area is known as the Bowl Hole, because of a large, seasonally flooding dune slack, but the cemetery itself is situated on a clay plateau just to the south of the Bowl Hole.

In 1998 the B.R.P. set out to find the cemetery and assess the level to which the site was being damaged by erosion and encroaching sycamore trees. Three test pits were excavated in the area suggested by the OS map. The first two pits found only wind blown sand while the third of these test pits revealed a cist burial. A 5m square trench was put in on the site of the third pit, and produced 7 grave cuts with a mixture of burial types and orientations. Further excavations from 1999 to 2004 produced at least 73 individual skeletons and a large quantity of disarticulated bone. Two of the individuals excavated in 1999 were radiocarbon dated, producing dates of between AD 560 to AD 670 for skeleton 130 and

AD640 to AD 730 for skeleton 129 (P. Wood, *pers comm*). The full extent of the cemetery has not yet been identified; the eastern edge of the site appears to have eroded into the Bowl Hole proper, and the density of burial decreases to the west, where there may be evidence for a boundary ditch. The southern and northern edges of the cemetery have also not been identified, but to the north the plateau ends, and as the burials in this region are generally shallow, erosion may have removed any evidence for boundaries. To the south the clay plateau extends for several hundred metres, and in 2004 exploratory trenches uncovered two burials around 25 metres to the south of the main cemetery area (shown as an inset in Figure 3.1.3a). These burials were very similar to those in the main area, and shared a similar orientation, suggesting that they are a continuation of the same cemetery. Further excavation is planned to explore the area between these two trenches. Based upon the density of burials excavated to date, the Bowl Hole burial ground may consist of several hundred burials, making this one of the largest Early Medieval cemeteries in Northumbria, and certainly one of the best preserved.

Several different types of burial are found in the Bowl Hole cemetery. Firstly there are the stone lined or cist graves for which the cemetery was first noted, these are orientated roughly east-west and occasionally contain animal bones, but no other grave goods. Some of the cists have been re-used or show signs of having been disturbed at some point in the past, and contain a mixture of crouched, supine and prone burials. The cist burials show a great deal of variation in form, ranging from a single vertical slab to a series of slabs lining several sides of the grave. Although erosion may have removed some side and capping slabs, no complete cists have been found, and only one burial has been excavated with a base slab, so this cemetery differs somewhat from the long cist and "head support" stone cemeteries found in Eastern Scotland (for example see (Carver, 2004)). It seems that at Bamburgh the cists may have been formed from a combination of stone and timber, although there are no surviving traces of timber, unlike at other sites such as Whithorn in Scotland (Hill, 1997). Other graves have no stone lining and these are generally in two depths; some are extremely shallow, often immediately below the turf, while others are up to 0.5m deep- indicating at least two phases of use. As the ground level changed over time, almost certainly as a result of erosion of the sand overlying the site, graves were dug more deeply into the underlying boulder clay. Like the cist burials, these individuals were in a variety of positions, and orientated either east-west or southeast-northwest, except for two individuals who had their heads to the west. Although the majority of the individuals were buried with their heads to the west, there is some variation in the precise orientation of the graves, probably as a result of seasonal variation in the sunrise. There was also a great deal of variation in the depth of the graves and the position of the bodies within the graves; bodies were placed in both prone and supine positions, extended and flexed and with a variety of upper and lower limb placements.

Some individuals were buried with simple grave goods including knife and belt sets, bone combs, latch lifters, small worked flints, animal bones, items of personal jewellery and faience beads. The cemetery was in use at the time that Christianity was brought to Northumberland (Stenton, 1971), so the simplicity of the grave goods could indicate the beginnings of Christian burial practices, although as discussed in Chapter 2, it is not possible to be certain that these individuals were Christian. The majority of the graves are shallow and some burials are immediately beneath the turf or within the base of the topsoil. Many of the graves show signs of erosion in the past, some of the skeletal material is scattered and in some cases entire elements are missing. However, a number of burials are significantly deeper, between 0.3 m and 0.5 m in depth. These deeper burials were found throughout the excavated area. Where it is possible to establish stratigraphic relationships between the burials the shallow burials are cut by the deep burials, in all but one case. At present, this difference in burial depth is believed to be the result of erosion during the lifetime of the cemetery; several burials at the southern end of the excavated area are cut through a deposit of windblown sand, and it is likely that this sand originally covered the entire cemetery. At some point, a storm or series of storms removed the sand, perhaps uncovering some of the graves. The cemetery continued to be used after this point, but as the ground surface was lower, graves were dug into the underlying clay. Such changes in the ground level may also explain the apparent lack of any grave markers (Wood, 2003).

Some of the graves are arranged in rough rows running from north to south, apparently respecting earlier burials. However, a small number of graves disturbed earlier burials, but where the new burial has been placed in such a way to avoid substantial damage to the earlier burial (for example, Skeletons 176 and 156 where the skull of Sk. 156 (the later burial) was deliberately positioned over the skull of Sk. 176). These features could be accounted for by differential erosion through the site, obscuring some graves but not others. It is possible that some or all of these cases could be the deliberate digging of new graves through older, visible graves, reflecting for example status or family ties. It should also be noted that most of the juvenile and infant burials are very shallow, and some are directly above, and in one case beside, other skeletons. This positioning may again be intentional.

The importance of Bamburgh in the Early Medieval kingdom of Northumbria is undisputed; it was the seat of the Bernician kings from the 6^{th} century AD, and before that was probably the site of the British fortress, *Din Guaire* (Higham, 1993, Rollason, 2003). However, the precise function of the fortress and surrounding area, and the activities that might have taken place there are uncertain. Although the excavations being carried out by the B.R.P. in the West Ward of the present Castle have yet to fully explore the Early Medieval archaeology of the fortress site, the evidence to date suggests the presence of a variety of wooden structures and possibly manufacturing industries and metalworking at the site (P. Gething, *pers comm*). Large quantities of animal bones have been excavated, both from the unpublished excavations by Brian Hope-Taylor and by the B.R.P., many of which show evidence for butchery and processing. Several large quern stones have also been found, although these are yet to be securely dated. The fortress at Bamburgh may have served as a centre for industry, or for centralising food processing, perhaps where food-rent was collected and re-distributed, as is suggested for the nearby palace site at Yeavering (O'Brien, 2002). The fortress was also a defensive structure, and several arrow or small spearheads have also been found, although it is possible that these are later than the period in question.

The *urbs* and the *villa regia* recorded in the documentary sources appear to have been separate but linked settlements, represented by the village and the fortress on the rock outcrop. As these two settlements were separate, it is reasonable to expect that they each had their own burial site. From the mid 7th century AD a church dedicated to St. Peter was present within the fortress, where the relics of St. Oswald were kept, probably on the site of the present chapel. This church may have been used for the burial of certain individuals, but space for burials within the fortress site is extremely limited. Consequently, a burial ground outside the fortress, but within sight of it, would be an ideal solution for this problem (Wood, 2003). It is possible that the Bowl Hole cemetery was the burial ground associated with the *urbs*. Interestingly the only place in the modern castle where the cemetery is visible is from the site of the ruined chapel, a fact that may support the link between the cemetery and the population within the fortress. Furthermore, there are two suspected burial mounds to the south-west of the cemetery, one of which is a scheduled monument. Early Medieval cemeteries are known to shift over time, sometimes by as much as several hundred metres, an example being Sutton Hoo, where excavations by Suffolk County Archaeological Service in advance of the construction of a new visitor centre in 2000 revealed a 6th or 7th century inhumation cemetery some 500 metres to the north of the 7th century burial mounds (Suffolk-County-Council, 2001). Therefore, the burial mounds at Bamburgh may have served as a focus for an earlier cemetery, which would also have been visible from the fortress, but separate from the village.

The location of the Bowl Hole cemetery in relation to the fortress and the vill may be significant, and could be related to the status and role of the population that used it. The cemetery is located within sight of the fortress and the sea, but not the present village, which is screened from view by a wooded ridge. This may indicate that the people buried in the Bowl Hole cemetery were somehow separate from the vill, as they were not buried in the churchyard, which was almost certainly in use at the same time. Preliminary analyses of oxygen, strontium and lead stable isotopes from the tooth enamel from some of the skeletons from the Bowl Hole adds additional support to this idea; of the individuals analysed to date, only around half grew up in the immediate area, the remainder probably having grown up in the wider kingdom of Northumbria. One individual may have come from Iona or Ireland while three individuals may have come from northern Scandinavia (P Budd, *pers. comm*). The high proportion of individual buried at the Bowl Hole who did not grow up at Bamburgh may indicate that this was a cemetery specifically reserved for "outsiders" and their families, who had come to Bamburgh for economic or political purposes. The apparently "normal" demographic profile of the skeletal sample argues against this being a cemetery simply for a group of mobile individuals; the demographic profile instead suggests settled family groups.

The Bowl Hole burial ground is somewhat later than those at Norton Mill Lane and Castledyke South, although there is some overlap in the radiocarbon dates. Consequently the burial practices are different, and may be more difficult to interpret. The date of the site, and the particular history of Bamburgh suggest that the individuals buried in the Bowl Hole cemetery may have been Christian, or on the cusp of Christianity, so this may have had an influence upon the burial practices at this site. While the type and location of the grave goods indicate that the individuals were buried fully clothed or shrouded, there were none of the weapon burials or elaborate jewellery seen at the earlier sites. As there are few of the objects and assemblages commonly used in methods of status identification, other techniques must be employed. The burials were divided into the following four artefact groups on the basis of the objects associated with each burial. To differentiate from the methods used to divide individuals into Artefact Groups at Castledyke and Norton Mill Lane, the groups at Bamburgh were given letters rather than numbers.

A total of 73 burials have been excavated to date, of which 40 individuals were suitable for inclusion in the present study. Over half of the burials from Bamburgh had no grave goods, and these were placed into Group A. Group B burials had a single animal bone, tooth or shells, or a potsherd. Although these are the type of items that may have simply been residual in the soil at the time of burial, the location of these items in the burials suggests otherwise; in one case a whole sheep/goat horn was placed over the head of the individual. Several of the Group B burials also had partial cist slabs or stones placed around the body. Animal bones were included in the burials more frequently at Bamburgh than at Castledyke and Mill Lane, and the individuals in Group C had several deliberately placed animal bones or teeth, but no other items. Two of the individuals from Group C were buried in graves with partial cist linings, with animal bones were carefully placed over or around the body, particularly on the chest or at the shoulder. All of the Group C individuals were males, although females did have animal bones in association with other objects. The meaning of these animal bones is unclear; Lucy has suggested that in "Final Phase" cemeteries they are more frequently associated with older individuals (Lucy, 2000, Lucy, 1998), and this was the case at Bamburgh. They may also be indicative of ritual feasting at the graveside, of the kind that was prohibited by the church in Early Medieval England (Taylor 2001 pp 141). Evidence for graveside feasting which may have served a similar purpose has been identified at other cemetery sites such as the late Mesolithic sites of Teviec and Hoedic in Brittany (Schulting, 1996).

Individuals with several iron objects, such as knives, buckles and pins were placed into Group D. One individual in this group had a set of latch-lifters and a "flint and steel" firelighter set, found at the waist, so probably originally in a pouch or pocket. Individuals of both sexes were found with iron artefacts, but the majority of individuals were female. All of the Group D individuals were middle aged or older. The following lists the artefact types that were present in each of the four artefact groups at Bamburgh:

Artefact Groups at Bamburgh:

Group A - No artefacts

Group B - Single animal bone or tooth or shells

Group C - Multiple animal bones, deliberately placed around the body

Group D - Multiple iron objects

Figure 3.1.4a shows the Bowl Hole cemetery at Bamburgh at the end of the 2005 season. The grave cuts of the skeletons that were examined in this study are colour coded according to their artefact groups. Juveniles and individuals that were not examined are not coloured. A red skeleton "line drawing" indicates that the individual was buried in a prone position while a blue skeleton indicates a supine burial. There does not seem to have been an association between burial position and other burial practices. From this figure it appears that there was some zoning of artefact groups at Bamburgh, with a cluster of Group B burials in a rough row along the south-western region of the cemetery. The individuals from the other three artefact groups were more evenly distributed across the site.

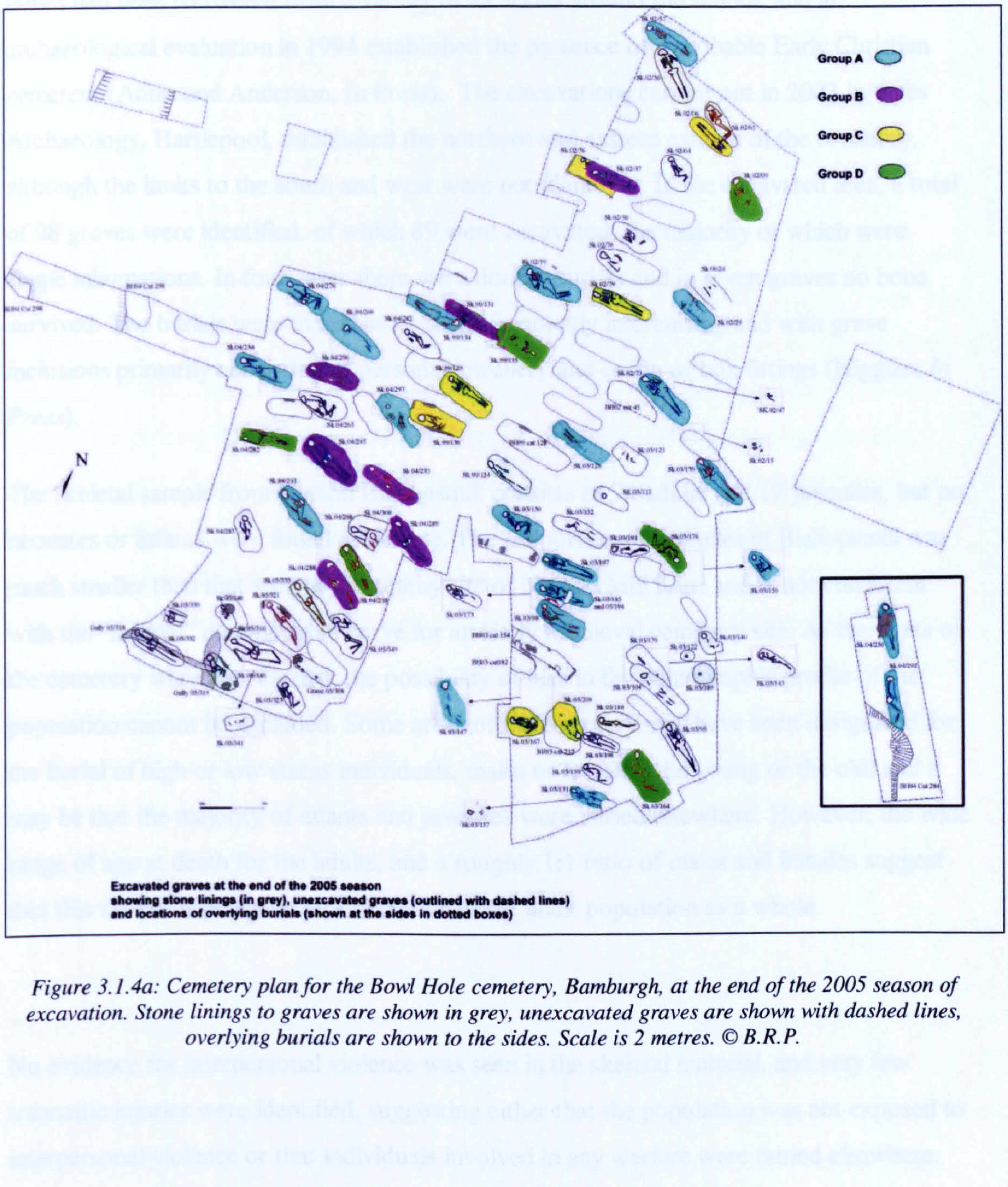


Figure 3.1.4a: Cemetery plan for the Bowl Hole cemetery, Bamburgh, at the end of the 2005 season of excavation. Stone linings to graves are shown in grey, unexcavated graves are shown with dashed lines, overlying burials are shown to the sides. Scale is 2 metres. © B.R.P.

3.1.5: Norton Bishopsmill School, North Yorkshire

In 2003, during excavations prior to an extension of Bishopsmill School, Norton, a large number of inhumation burials were encountered. During the 19th and 20th centuries human bones had been recovered from a variety of locations around the school, and an archaeological evaluation in 1994 established the presence of a probable Early Christian cemetery (Annis and Anderson, In Press). The excavations carried out in 2003 by Tees Archaeology, Hartlepool, established the northern and eastern extents of the cemetery, although the limits to the south and west were not identified. In the excavated area, a total of 98 graves were identified, of which 89 were excavated, the majority of which were single inhumations. In four cases there were double burials and in seven graves no bone survived. The burials were in east-west rows, frequently intercutting and with grave inclusions primarily consisting of personal jewellery and coffin or box fittings (Higgins, *In Press*).

The skeletal sample from Norton Bishopsmill consists of 74 adults and 12 juveniles, but no neonates or infants were found at the site. The proportion of juveniles at Bishopsmill was much smaller than that seen at the nearby site of Norton Mill Lane and is not consistent with the "normal" demographic curve for an Early Medieval cemetery site. As the limits of the cemetery were not reached, the possibility of bias in the demographic profile of the population cannot be excluded. Some areas of the cemetery may have been designated for the burial of high or low status individuals, males or females, the young or the old, and it may be that the majority of infants and juveniles were buried elsewhere. However, the wide range of age at death for the adults, and a roughly 1:1 ratio of males and females suggest that this sample is probably representative of the adult population as a whole.

No evidence for interpersonal violence was seen in the skeletal material, and very few traumatic injuries were identified, suggesting either that the population was not exposed to interpersonal violence or that individuals involved in any warfare were buried elsewhere. Levels of dental calculus were relatively high, with the majority of adults being affected, but the level of dental caries was low, although a little more frequent in males than in females. In comparison with the Norton Mill Lane sample the prevalence of dental enamel hypoplasia was less frequent at Bishopsmill, possibly indicating a lower level of childhood stress than at the earlier site. The frequency of infections was low, but the frequency of tibial periostitis was higher than that seen in other Early Medieval samples (8.1%, at Bishopsmill, in comparison to 6.5% at other sites), perhaps indicating that the agricultural lifestyle at Bishopsmill led to greater risk of infection (Higgins, *In Press*).

Radiocarbon 14 dates were obtained from four of the skeletons, all at 95.4% probability; Sk 190 (an older probable male, grave no. 188) was dated to AD 660- AD 790, Sk 330 (an older probable male associated with coffin fittings, grave no. 98) was dated to AD 680 – AD 890, Sk 333 (a young middle aged probable female associated with coffin or box fittings, grave no. 331) was dated to AD 650 – AD 770, and finally Sk 410 (a middle aged probable male, grave no. 408) yielded a date range of AD 710 – AD 910 (*pers. comm.* Paul G. Johnson of Northern Archaeological Associates; Carbon 14 dating carried out by Beta Analytical, USA). These radiocarbon dates tie in well with the burial practices observed at the site, supporting the hypothesis that this site represents an Early Christian cemetery dating from the 7th to 9th centuries AD. The C14 dates also suggest that the cemetery was in use for a considerable length of time, perhaps up to 300 years, although the dates all overlap so the lifetime of the cemetery may have been much shorter. Two main phases of use were identified, based upon the radiocarbon dates and density of burials; the majority of the burials were part of Phase I, in the western part of the excavated area, while Phase II was centred around grave 408, to the southeast. The density of burial was greatest in the south of the site, and this area also had the greatest density of individuals with coffin fittings or other artefacts. This clustering may have developed around a focal point such as an earlier grave, or indicate the proximity of a church building; a hypothesis that could be tested with further excavation.

At present the relationship between the cemetery at Bishopsmill School and the earlier "pagan" cemetery is not fully understood, but as the earlier cemetery is only 200 yards or so to the east (P.G. Johnson and R. Annis, *pers. comm*), it is likely that the burials at Bishopsmill School represent a continuity of occupation following conversion to Christianity. In continental Europe the practice of continuing to bury individuals in a pre-existing cemetery, following the conversion to Christianity was actively discouraged; requiring either the removal of earlier burials or the formation of a new burial ground

(Effros, 1997). Norton Bishopsmill may represent such a burial ground in relation to the site at Norton Mill Lane.

Norton Bishopsmill had the fewest and least varied grave goods associated with the burials. The relative lack of grave goods suggests that this is an early Christian site, and as such social stratification may be less visible at this site. However, as at Bamburgh, there was some variation in the artefacts included with the burials. While the majority of individuals did not have grave goods, some did have objects included in the grave, and others were apparently buried in coffins or chests. These variations may still be useful as indicators of social stratification within the population. Grave depth has been utilised as an indicator of investment of energy in the burial of an individual, and hence an indication of social status, however, at Bishopsmill there was no association between grave depth and the types of artefacts or burial practices.

As at Bamburgh, to differentiate the methods used to divide the sample into groups on the basis of grave goods, from the methods used at the two earlier sites, the Artefact Groups were given letters rather than numbers. At Norton Bishopsmill, over 60% of the individuals from the sample were apparently buried without grave goods, and these individuals were placed into Group A. As with the other sites, it is possible that these individuals were buried with organic items that did not survive to excavation. Individuals with animal bones and/or teeth were placed into Group B, and as at Bamburgh some of the animal bones, particularly mandibles, were deliberately placed beside the body. Individuals in Group C had pottery, worked stone or flint objects, and one individual from this group also had a copper finger ring on the middle finger of the right hand. Individuals from Group C had iron objects in the grave, and in the majority of cases these were probably coffin or box fittings and nails. Although it is more difficult to interpret these burials, burial within a coffin or box may suggest that the individual was higher status than those who were buried without any items. These differences in burial practice may also reflect ideological differences within the sample, which may have been related to the individual's position within society. All artefact groups were present in both of the phases identified by the excavators at Bishopsmill. The following lists the artefact types that were present in each of the four artefact groups at Norton Bishopsmill:

Artefact Groups at Norton Bishopsmill:

Group A – No grave goods

Group B – Animal bones or teeth

Group C – Pottery, worked stone or flint

Group D – Iron objects or coffin fittings

Of the total of 74 adult individuals excavated from this site, 40 skeletons were selected for study. Figures 3.1.5a and 3.1.5b show the plans of the excavated areas with Phase I and Phase II graves; the clustering of graves in the south of the site is clear. The graves containing individuals examined in this study are highlighted in colour, indicating the artefact groups of the individuals examined. The full site report for Norton Bishopsmill was in press at the time of writing of this thesis.

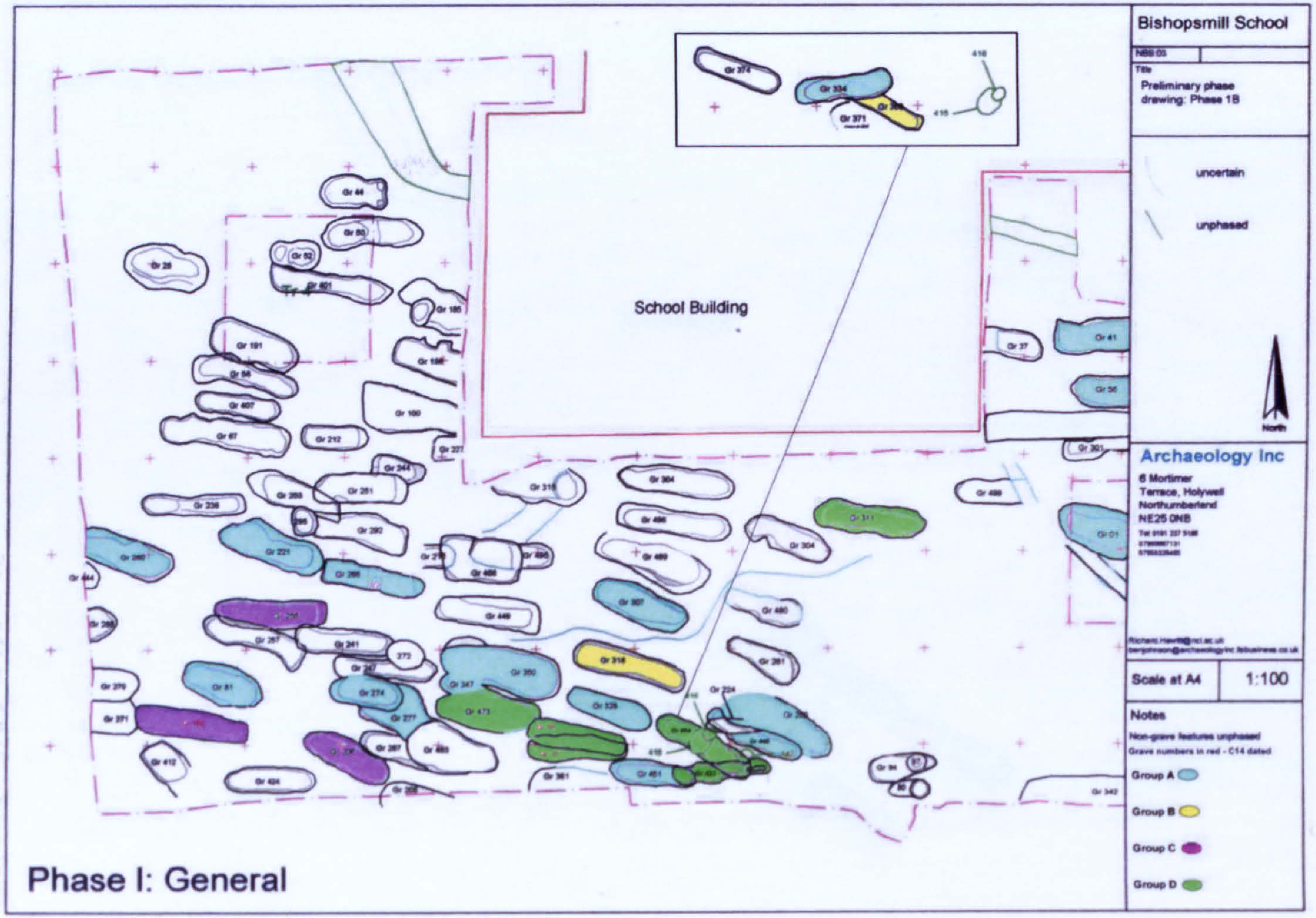


Figure 3.1.5a: Cemetery plan for Norton Bishopsmill, Phase 1. Coloured fill indicates the artefact group. Adapted from interim plan provided by P.G. Johnson.

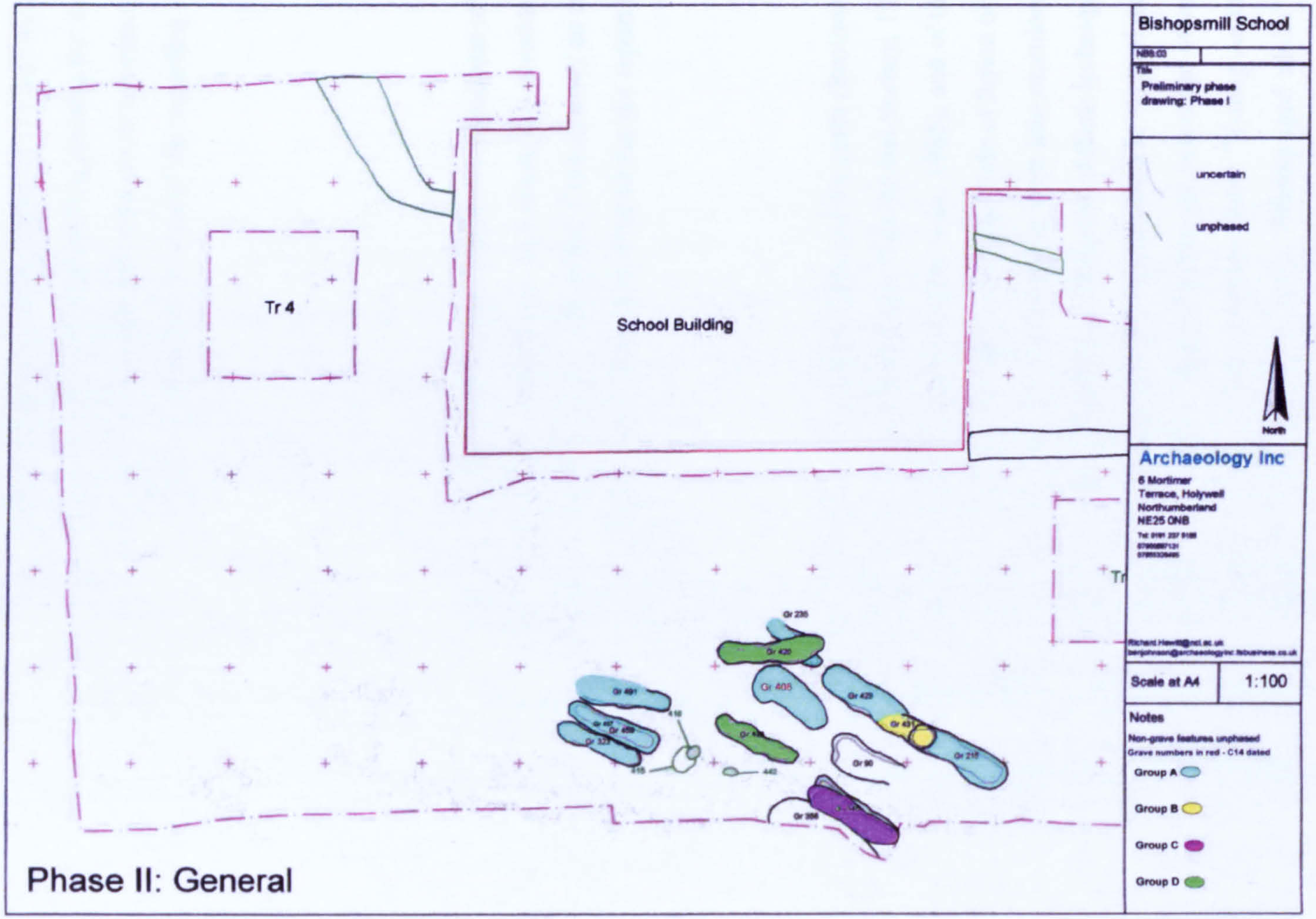


Figure 3.1.5b: Cemetery plan for Norton Bishopsmill, Phase 2. Coloured fill indicates the artefact group. Adapted from interim plan provided by P.G. Johnson.

3.2: Methods of Analysis

3.2.1: The Design of the Recording Form

To date, there are few studies that have examined multiple indicators of activity related change, and as a consequence there are no standardised recording systems for studies of multiple markers. The recording form was designed so that data could be collected as efficiently as possible, directly onto a laptop computer. A copy of the recording form is included in Appendix 1.

3.2.2: Age and Sex

The techniques used to age and sex skeletal material have been developed and refined since some of the skeletal samples were initially examined and, as a result, it is possible that the original report data relating to age and sex may be inaccurate. Consequently an estimation of age and sex was made for each individual, without reference to the site report or grave goods associated with the skeleton.

The methods used for estimating age at death were attrition of the teeth (Brothwell, 1989), degeneration of the joint surfaces of the pubic symphysis (Brooks and Suchey, 1990) and degeneration of the auricular surface of the ilium (Lovejoy *et al.*, 1985), and of the sternal ends of the ribs (Loth and Iscan, 1989). For younger adults, the state of fusion of the iliac crest, the medial clavicle and the ventral rings of the vertebrae were also examined (Cox, 2000). Where the level of preservation permitted, a combination of these techniques was used. As it is difficult to assign a specific chronological age at death to skeletal material, particularly as the techniques mentioned above generally give age as a range of years, the individuals were placed into age categories. These categories were; "Young Adults" (from 17 to 25 years), "Young/middle aged adults" (26-30 years), "Middle aged adults" (31-40 years), and "Older adults" (41+). Individuals that could not be aged more precisely were recorded as "Adult". Where different techniques gave a variety of ages for one individual, the most frequently reported age was used.

Biological sex was determined using the morphology of the pelvis (Hager, 1996, Phenice, 1969), the morphology of the skull and vertical diameter of the humeral and femoral head and the glenoid cavity of the scapula (Bass, 1995). Where assessment of biological sex was not possible, or the individual displayed both male and female features, the sex was recorded as "unknown". The individuals were not further subdivided into "possible females" and "possible males", as the skeletal samples were too small for meaningful results to be obtained from such small groupings. Therefore, while individuals are referred to as female or male, this is the estimation of sex rather than known sex.

The markers of activity related stress that were examined in this study, osteoarthritis, enthesopathies, Schmorl's nodes and asymmetry of the humerus and femur, were selected for use in this study as they are the most widely used markers of activity in archaeological samples (Jurmain, 1999). As has been discussed in Section 1.4, there is clinical evidence for some associations between all these skeletal changes and physical activity, evidence which has prompted their examination in archaeological skeletal material. However, the aetiology of all these changes is not fully understood, particularly osteoarthritis and enthesopathies, so by examining patterns of several skeletal changes it may be possible to identify which changes are more or less sensitive to influences such as age and sex. The methods used to record each of the skeletal changes will be discussed below.

3.2.3: Osteoarthritis

In a clinical context, the diagnosis of osteoarthritis (OA) is relatively simple- when a patient presents with joint pain, with swelling and/or crepitus, it is likely that they are suffering from OA, and this diagnosis can be confirmed easily in radiographs by the presence of joint space narrowing and marginal osteophytes. However, in an archaeological context it is not possible to consult the "patient" to identify their symptoms and consequently the disease can only be identified by examination of any changes to the joint surface and surrounding area. It is not possible to identify narrowing of the joint space in skeletal material, but it is possible to see other changes that result from the condition, and in some cases these changes can be seen much more easily in dry bone than in living tissue. As OA originates from the degeneration of the articular cartilage, the major changes resulting from the disease occur to the joint surface and margins. As discussed in Chapter 1, Section 1.4.1, the unequivocal indicator that an individual suffered from OA is the presence of eburnation on the joint surface (Rogers and Waldron, 1995). In skeletal material eburnation is relatively easy to identify; the normal appearance of joint surfaces is disrupted by regions of extremely smooth, polished bone that reflects light. These areas can be small and may only be visible when light reflects from the area of eburnation. Consequently the skeletal material must not only be well preserved, but also sufficiently clean. Eburnation also feels smooth to the touch and can be felt by running a finger over the joint surface. In some cases the area of eburnation may be grooved, particularly in the knee and elbow, as a result of the bone of the joint surfaces rubbing against each other for prolonged periods. Porosity of the joint surface, osteophytes and subchondral cysts may also indicate osteoarthritis, but are not as definitive as the presence of eburnation (Rogers and Waldron, 1995).

Many other studies of the prevalence of osteoarthritis within archaeological samples have attempted to identify the relative severity of cases of OA. Lesions that are more "severe" are assumed to have caused more discomfort to the individual, or to have been more long-standing than less "severe" lesions. However this may not be the case with osteoarthritis (see Chapter 1, section 1.4.1). Although in a clinical context pain is considered to be a diagnostic criterion of the presence of OA, there is no relationship between the degree of pain and the morphological appearance of the joint in question. A patient may have severe pain and few or no observable changes to the joint surface, or conversely may have radiological changes indicative of OA, but no symptoms (Rogers and Waldron 1995, pp 101-103). Although in a living individual it may be possible to identify, through the patient's history, when they first began to suffer from OA, and how long they have had the condition this is not the case for archaeological material- we only see the appearance of the lesion at the time of death. The disease also progresses at different rates in different individuals, so the apparent "severity" of a lesion in a living individual may not be related to the length of time that they have had the condition. Therefore, it is not possible to relate the "severity" of a lesion with the state of progression of the disease (Rogers and Waldron 1995, pp 102-105). Consequently, this study records only the presence or absence of changes to the joint surface.

Limb	Joint surface examined	Functional Joint
Upper	Glenoid Fossa Proximal Humerus	Shoulder
	Distal Humerus Proximal Ulna Proximal Radius	Elbow
	Distal Ulna Distal Radius	Wrist
Lower	Acetabulum Femoral Head	Hip
	Distal Femur Patella Proximal Tibia Proximal Fibula	Knee
	Distal Tibia Distal Fibula	Ankle

Table 3.2.3a: Joint surfaces examined for the presence of osteoarthritis

The major appendicular joints of the skeleton were observed for changes, and both sides were examined where preservation of the remains allowed. Joint surfaces that were not present were recorded as such in order that true prevalence rates of joint disease could be calculated. All of the appendicular joints examined consist of two articular surfaces and, although both surfaces are involved in the development of osteoarthritis, the type of changes seen are not always the same on the two surfaces of one joint. Issues of preservation can also influence the portions of a joint that are present for examination, and if the affected portion of a joint is not present, cases of OA can be missed. Therefore, all joint surfaces were examined and recorded as separate surfaces rather than as components of a functioning joint. However, during analysis of the results the joint surfaces were also considered as groups, which make up the major joints of the shoulder, elbow, wrist, hip, knee and ankle; the "functional joints". A "functional joint" was considered to be present where one or more of the component joint surfaces were present.

The articular joints of the vertebral column and the joints of the hands and feet were not examined, for several reasons. Although some studies have shown relationships between the presence of osteoarthritic changes and handedness (Buckland-Wright *et al.*, 1991, Waldron, 1996), these changes tend to relate to specific joints which may not be preserved in archaeological material. Other studies produced conflicting results (Lane *et al.*, 1989, Lawrence, 1961, Waldron and Cox, 1989), indicating that OA in the hand may not be a good indicator of activity patterns. In many cases the small bones of the hands and feet were not present or were fragmentary and poorly preserved, and thus the data from these joints would be limited in relation to the time spent identifying and observing the joint surfaces. The vertebral column suffers from similar issues to the hands and feet. Furthermore, preservation of the vertebral column in the samples under study was often poor, and it would be extremely time consuming to identify and record each of the 70 articular facets (118 including the rib articulations), in a fragmentary spinal column, when large numbers of skeletons are to be examined. The relationships between OA in the vertebral column and physical activity levels are also uncertain. The development of spinal OA is influenced by bipedalism, posture, trauma, and age as well as the possible impact of physical activities. A study of degenerative changes in the vertebral column in relation to social status groups in the St. Andrew's Fishergate cemetery in York found that there was no statistical significance in the patterns of spinal degenerative changes between the groups in the cemetery (Knüsel *et al.*, 1997). This study examined a number of different spinal conditions that may have different causes, and amalgamated the results for each condition in the final analysis. This practice may have obscured any patterns that the occurrences of these different conditions could have shown. However, it does seem that degenerative changes in the vertebral column may not be as well suited to studies of the impact of physical activity upon the body as other regions of the body, particularly because of the biological constraints imposed upon the spine by bipedalism (Knüsel *et al* 1997, pp 493).

The diagnostic criteria for osteoarthritis in the skeletal material were based on Rogers and Waldron (1995, pp 43-44). Joints were examined for the presence of eburnation (E), osteophytes (OP), and porosity (P), and the presence of any of these changes was recorded on the form. The presence of eburnation was defined according to the description given above. Osteophytes were defined as the presence of new bone on or around the joint surface, varying from small specks to florid bone growth. Porosity was defined as any change from small clusters of "pinpricks" to substantial holes in the joint surface. Where porosity and osteophytes (POP) were observed, this was considered to be possible osteoarthritis (?OA), where eburnation was observed, with or without the presence of other changes, this was considered to be a definite case of osteoarthritis (OA). As other studies have defined osteoarthritis both by the presence of eburnation and by the presence of osteophytes alone, both of these changes were recorded to permit comparison with other studies. By recording possible cases of OA it is also possible to examine any patterns in the presence of osteophytes at the joints that may have been associated with age or the prevalence of enthesopathies (which have been associated with general "bone forming" – see section 1.4). Figure 3.2.3a shows fine "pinprick" porosity (white arrow) and larger holes in the joint surface (blue arrow), on the left patella, both of which were recorded as porosity. Small osteophytes are present at the margins of the joint surface, particularly at the apex. This joint surface was recorded as having possible osteoarthritis.

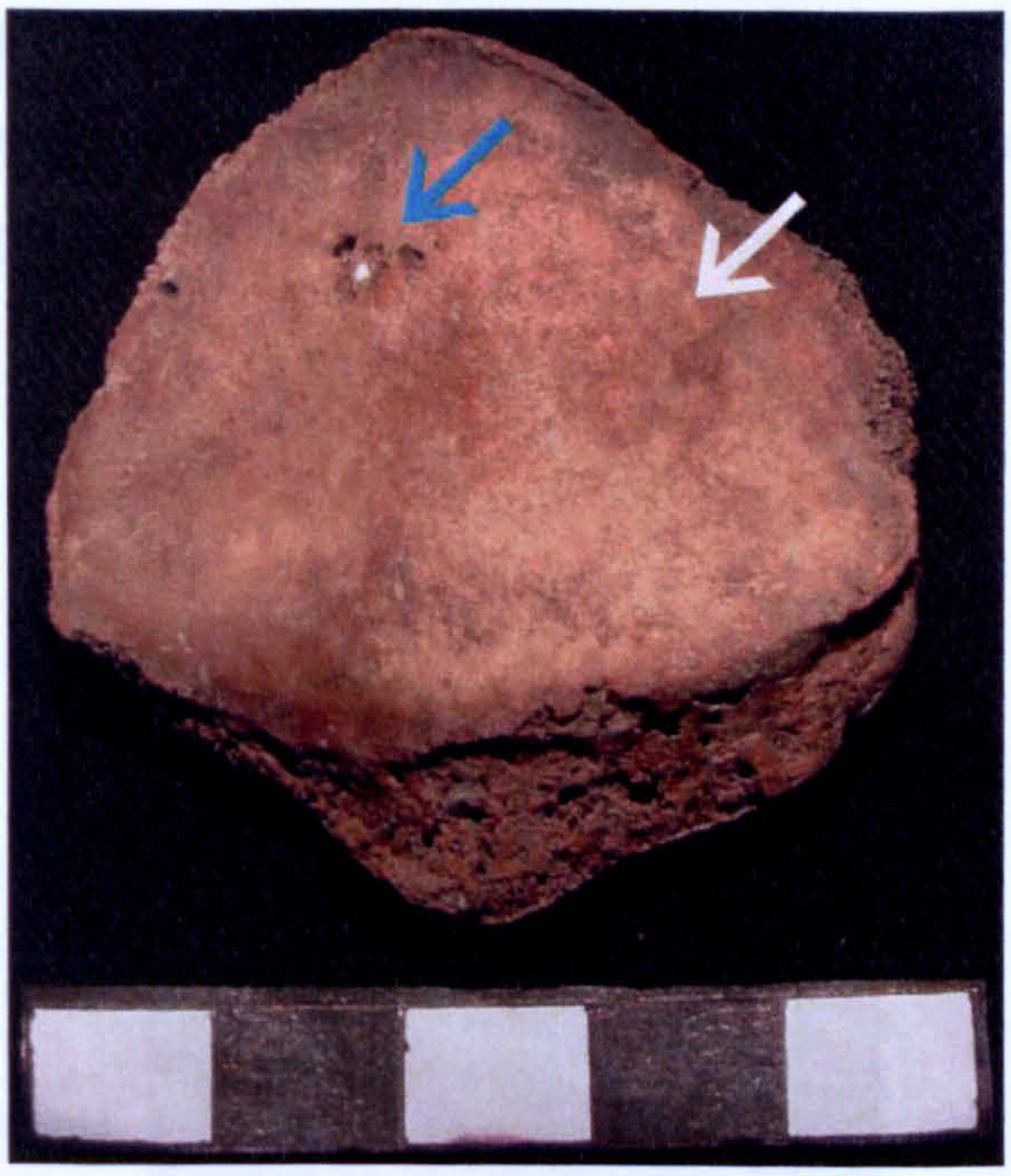


Figure 3.2.3a: Fine porosity (white arrow) and larger scale porosity (blue arrow) in a left patella from SK 89, Castledyke South. Osteophytes are present around the margins of the joint surface. Scale: 5 cm.

Figure 3.2.3b shows the right glenoid fossa and humeral head from SK 30, from Castledyke South. The white arrows define areas of eburnation on both joint surfaces. Porosity is visible in the area of eburnation on the glenoid fossa, and osteophytes are present around the margins of the joint surface. These joint surfaces were recorded as having osteoarthritis.

Figure 3.2.3b: Right glenoid fossa and humeral head from SK 30, Castledyke South. Eburnation is visible on both joint surfaces (white arrows)

Figure 3.2.3c shows the right proximal ulna from SK 159, from Castledyke South. This joint surface has marginal osteophytes, particularly around the proximal and distal margins. As no eburnation was present this joint was recorded as possible osteoarthritis

Figure 3.2.3c: Right proximal ulna with marginal osteophytes, from SK 159 Castledyke South. Scale: 5 cm.

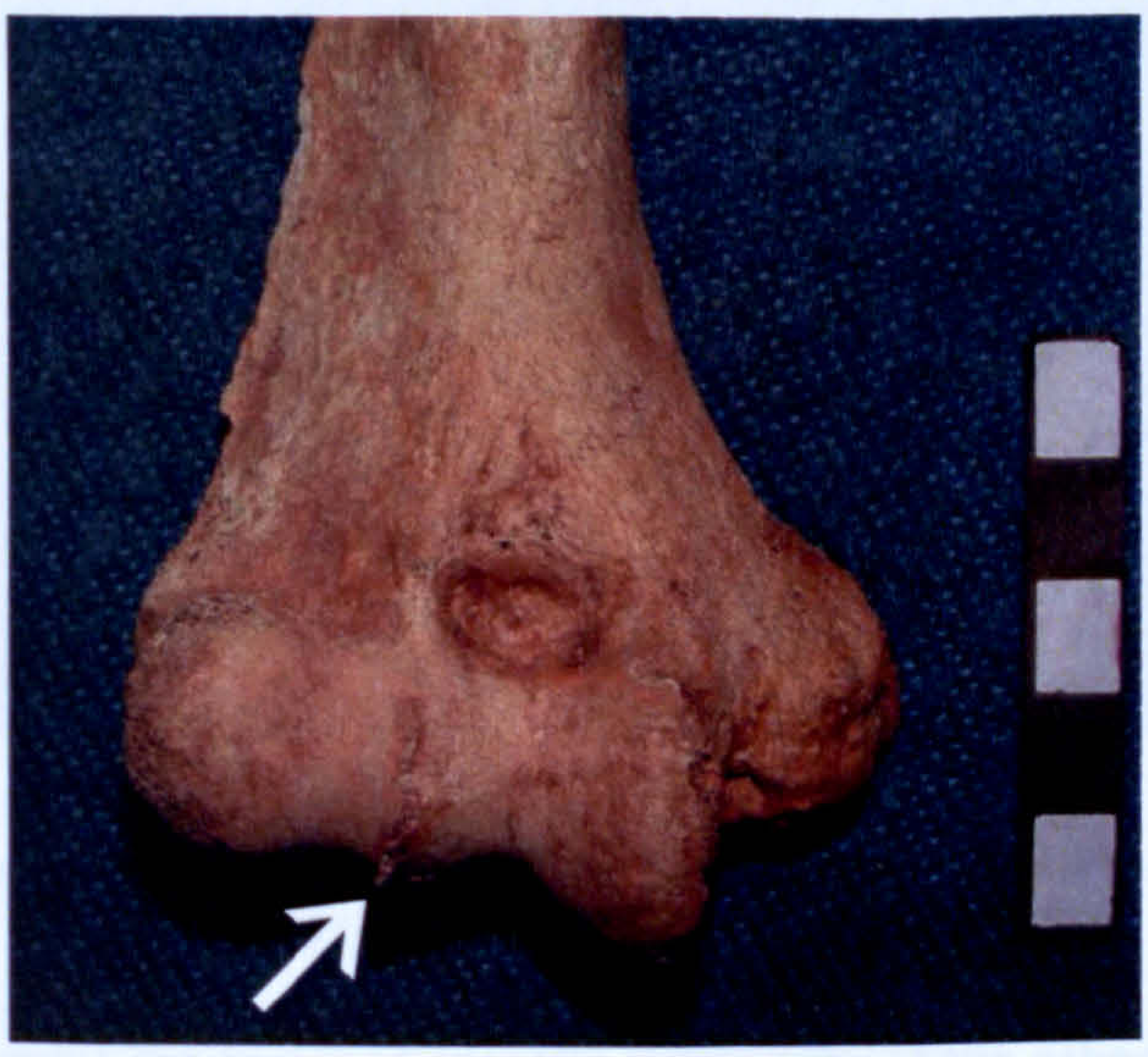


Figure 3.2.3d: Right distal humerus with osteophytes on the articular surface (white arrow), from SK 03 176, Bamburgh. Scale: 5cm

Where osteophytes were observed on the joint surface, as in the distal humerus shown in figure 3.2.3d (white arrow), these were also recorded. As eburnation was not present in this joint surface, it was recorded as possible osteoarthritis.

3.2.4: Schmorl's Nodes

Since they were first reported by Schmorl in 1927, these lesions, found on the superior and inferior surfaces of the vertebral bodies, have been thought to be the result of herniation of the intervertebral disc into the vertebral surface. In a clinical context, Schmorl's nodes are identified in radiographs and CT scans as lesions in the vertebral endplate, often with an indistinct sclerotic marginal line (Peng *et al.*, 2003). In sections of cadaveric vertebral columns it is possible to see the tissue of the intervertebral disc intruding into the surface of the vertebral body (Schmorl and Junghanns, 1971). In archaeological material, these lesions are identifiable as shallow indentations in the vertebral surfaces, round or elongated in shape, usually with rounded, remodelled edges (Rogers and Waldron, 1995). Schmorl's nodes are typically found in the centre or slightly to the posterior of the vertebral endplate, on the mid coronal axis (Saluja *et al.*, 1986), and are most frequently seen in the thoracic and lumbar regions of the vertebral column (Jurmain, 1999).

Figure 3.2.4a: Small Schmorl's nodes (white arrows) in the superior surfaces of thoracic vertebrae from SK 99 131, from Bamburgh. Scale: 5cm

Although Schmorl's nodes are easier to identify than some of the other lesions used as markers of musculoskeletal stress, they can be varied in appearance. Schmorl's nodes can be small and well defined, like those shown in Figure 3.2.4a, or they can be much larger and more irregularly shaped, as in the case of the lesion on the superior surface of the 10^{th} thoracic vertebra shown in figure 3.2.4b.

Figure 3.2.4b: Thoracic vertebra with irregular Schmorl's node on the superior surface. SK 19, Castledyke South. Scale: 5cm

The presence of absence of Schmorl's nodes (SN) was recorded on the form for each vertebral surface in the vertebral column, including the first body of the sacrum. Although it is possible for more that one Schmorl's node to develop on a vertebral surface, the number of lesions was not recorded. Where a vertebral surface was not present or not observable due to damage or fusion this was also recorded.

3.2.5: Enthesopathies

Although some systems of recording and scoring changes to the entheses have been developed, there are many limitations to the usefulness of these systems. The most widely used systems are those based upon the methods developed by Hawkey (1988 and 1995) and Robb (1998). Both systems are based upon scoring or grading the changes seen on the bones, using photographs or schematic images and descriptions of the various grades. These systems can be very subjective as the images given in the original publications are by no means ideal or clear; it is very difficult to depict a three-dimensional change to the attachment site via a two-dimensional medium such as photography, and the descriptions can be interpreted in many different ways. One observer's idea of what constitutes a "rugose" change may be very different from that of another observer. Perhaps the only solution to this problem would be to develop a series of casts showing the various grades and changes, although as the relationship between the changes seen and the degree of mechanical stress which may have caused them is unknown (Benjamin *et al.*, 2002), it may not be relevant to attempt to score for severity.

A further problem is the fact that the appearance and "severity" of enthesopathies can be influenced by age (Weiss, 2003), sex, hormonal levels and disease (al-Oumaoui *et al.*, 2004, Rogers *et al.*, 1997), and the levels of changes may also be related to the genetic background of the population in question. The methods for recording enthesopathies were developed using samples from North America (Hawkey and Merbs, 1995) and Iron Age Italy (Robb, 1998). It is likely that there will be considerable genetic variation between these populations and those from Early Medieval England, which could affect the manifestation of enthesopathies in the skeleton. Enthesopathies in the lower limb are thought to be correlated with body mass (Weiss, 2003), but as the upper limb is not used in locomotion in humans, changes to the entheses in the upper limb should be independent of body mass. A comparison of the patterns of enthesopathies in the upper and lower limbs could shed light upon the influence of weight bearing on the formation of these changes.

The major long bones from the upper and lower limbs, and the clavicle and patella were examined for changes to the entheses listed in Table 3.2.5a and Table 3.2.5b; these tables also list the muscles and/or ligaments that attach at each enthesis and their main functions. These entheses were selected as they are easy to identify and represent the major muscles and ligaments of the upper and lower limbs. Entheses of the vertebral column, hands and feet were not examined, for the same reasons that these elements were not examined for OA.

Upper Limb	Enthesis	Muscle or Ligament	Function
Clavicle	Costal Tuberosity	Costoclavicular ligament	Strengthens sternoclavicular joint
	Subclavian Sulcus	Subclavius muscle	Draws shoulder forward and downward, steadies clavicle
	Conoid Tubercle	Conoid ligament	Reinforces joint between scapular and clavicle
	Trapezoid Line	Trapezoid Ligament	Reinforces joint between scapular and clavicle
	Superior Surface	Trapezius muscle	Elevates scapula, stabilizes scapula when carrying weight in the hand
		Deltoideus muscle	Flexes and medially rotates arm
		Pectoralis Major muscle	Adducts and medially rotates arm, flexes arm from full extension
Ulna	Olecranon	Triceps brachii	Extends forearm, aids in adduction of arm
	Ulna Tuberosity	Brachialis muscle	Flexes forearm
	Interosseous Crest	Interosseous membrane	Houses flexor and extensor muscles acting on wrist
	Pronator Ridge	Pronator quadratus muscle	Pronates forearm and hand
Radius	Radial Tuberosity	Biceps brachii muscle	Supinates and flexes forearm, weakly flexes arm at shoulder
	Interosseous Crest	Interosseous membrane	Houses flexor and extensor muscles acting on wrist
	Oblique Line	Extrinsic muscle of the hand	Flexes thumb, flexes fingers
	Pronator Teres Insertion	Pronator teres muscle	Pronates and flexes forearm
	Dorsal Tubercle	N/A	Houses tendons for extrinsic extensors of the hand
Humerus	Lesser Tubercle	Subscapularis muscle	Medially rotates arm, stabilizes glenohumeral joint
	Greater Tubercle	Supraspinatus muscle	Draws humerus to glenoid fossa, aids in abduction of the arm
		Infraspinatus muscle	Draws humerus to glenoid fossa, laterally rotates and abducts arm
		Teres Minor muscle	Draws humerus to glenoid fossa, laterally rotates and weakly adducts arm
	Bicipital Groove	Tendon of the long head of biceps brachii	Supinates and flexes forearm, weakly flexes arm at shoulder
	Crest of Greater Tubercle	Pectoralis Major muscle	Adducts and medially rotates arm, flexes and extends arm
	Crest of Lesser Tubercle	Teres Major muscle	Medially rotates arm, adducts arm, extends arm
	Deltoid Tuberosity	Deltoideus muscle	Flexes and medially rotates arm
	Lateral Epicondyle	Radial Collateral ligament	Flexes forearm, extends hand, extends fingers
	Medial Epicondyle	Ulna Collateral ligament	Flexes hand and fingers
		Pronator teres muscle	Pronates and flexes forearm

Table 3.2.5a: Entheses in the upper limb that were examined for changes, and the function of the muscle or ligament

Lower Limb	Enthesis	Muscle or Ligament	Function
Femur	Greater Trochanter	Gluteus Minimus muscle	Abducts femur at the hip and rotates thigh medially
		Gluteus Medius muscle	Abducts femur at the hip and rotates thigh medially
	Intertrochanteric Line	Iliofemoral ligament	Strengthens joint capsule of hip
	Trochanteric Fossa	Obturator externus	Laterally rotates thigh at the hip
	Lesser Trochanter	Iliacus muscle	Flexes thigh at the hip joint
		Psoas Major muscle	Flexes thigh at the hip joint, flexes vertebral column
	Quadrate Tubercle	Quadratus Femoris muscle	Laterally rotates thigh at the hip
	Gluteal Tuberosity	Gluteus Maximus muscle	Extends, abducts and laterally rotates thigh. Used only in forceful extension
	Spiral Line	Vastus Medialis muscle	Extends leg at knee joint
	Linea Aspera	Vastus muscles	Extends leg at knee joint
		Adductors Longis, Brevis and Magnus	Adduct, extend and flex thigh, assist in medial rotation and flexion
	Adductor Tubercle	Adductor Magnus	Adducts, extends and medially rotates thigh
Patella	Apex	Quadriceps Femoris tendon	Extends leg at knee joint, flexes thigh at hip, used when walking or kicking
	Proximal Margin	Vastus lateralis and medialis	Extends leg at knee joint
	Distal Margin	Quadriceps Femoris tendon	Extends leg at knee joint, flexes thigh at hip, used when walking or kicking
Tibia	Tibial Tuberosity	Quadriceps Femoris muscle	Extends leg at knee joint, flexes thigh at hip, used when walking or kicking
	Soleal Line	Popliteus muscle	Rotates leg medially, flexes leg, stabilizes knee
		Soleus muscle	Plantar flexes foot
	Superior Fibula Articulation	Tibialis Anterior muscle	Dorsiflexes foot at ankle, supinates foot
	Interosseous Crest	Interosseous membrane	Binds the tibia and fibula together, origin of extensors and flexors of the foot
	Fibula Notch	Tibiofibular ligament	Binds the distal tibia and fibula together to form the proximal ankle joint

Table 3.2.5b: Entheses in the lower limb that were examined for changes, and the function of the muscle or ligament

For the purposes of this study, the entheses examined were grouped together in to functional groups, representative of the major muscle and actions of the elements of the upper and lower limbs. The entheses were grouped as follows:

Upper limb:

Enthesis Group	Entheses
Clavicle	Costal tuberosity, subclavian sulcus, conoid tubercle. Trapezoid line, deltoideus and pectoralis
Humerus flex/ ext	Lesser tubercle, crest of lesser tubercle, deltoid tuberosity, greater tubercle, crest of greater tubercle
Forearm flex/ ext	Olecranon, lateral epicondyle, ulna tuberosity
Pronators/ supinators	Pronator teres insertion, pronator ridge, medial epicondyle, radial tuberosity, bicipital groove
Hand flex / ext	Radial oblique line, dorsal tubercle of the radius

Lower Limb

Enthesis Group	Entheses
Gluteus /adductor	Greater trochanter, adductor tubercle
Hip rotators	Intertrochanteric line, quadrate tubercle, trochanteric fossa
Femur Flexors /extensors	Lesser trochanter, gluteal tuberosity, spiral line, linea aspera
Quadriceps	Patella and tibial tuberosity
Foot Flexors	Soleal line, superior fibular articulation
Interosseous	Interosseous crest, fibula notch

Changes to the entheses were recorded as follows; bone formation (BF) was defined as the presence of new bone formation at the enthesis giving the region a rough appearance; "robusticity" (R) was defined as a smooth ridge at the enthesis and lytic changes (L) were defined as a groove or depression at the enthesis, with or without smooth edges. These changes were not exclusive to one enthesis, and all three changes could be present. Changes were not scored for severity, but where the changes seen were particularly robust or prolific, this was noted on the recording form. Where bone formation or robusticity was observed, this was recorded as possible enthesopathy as these more minor changes may have been associated with other factors as discussed in Section 1.4, and where both new bone formation and robusticity or lytic changes were observed, this was recorded as definite enthesopathy.

Figure 3.2.5a: 1 -Posterior view of the femora from Sk 99 131, Bamburgh, with no changes to the entheses. 2 – posterior view of left femur from Sk 07 Castledyke South showing changes to the linea aspera, greater and lesser trochanters and gluteal tuberosity. Scale in both images: 5 cm

Image 1 in Figure 3.2.5a shows the posterior view of the proximal left and right femora from Sk 99 131, from the Bowl Hole, Bamburgh. These bones did not have any changes to the entheses. Image 2 in Figure 3.2.5a shows the posterior view of the left femur from Sk 07, Castledyke South. This femur has bone formation and robusticity at the linea aspera, bone formation on the lesser trochanter and robusticity at the gluteal tuberosity. The scale in both images is 5 cm.

Figure 3.2.5b shows the right proximal radius from Sk 147, Castledyke South, with bone formation on the radial tuberosity and interosseous crest. The interosseous crest is also enlarged. The *biceps brachii*, which supinates and flexes the forearm, inserts into the radial tuberosity, and the *flexor pollicis longus*, which flexes the thumb, originates from the interosseous membrane (Stone and Stone, 2000).

Figure 3.2.5b: Right radius with bone formation on the radial tuberosity and interosseous crest (white arrows), from SK 147, Castledyke South. Scale: 5 cm

Figure 3.2.5c shows the right proximal humerus from Sk 167B, Castledyke South, the bicipital groove is very deep, and the crest of the greater tubercle is robust with some bone formation (insertion of the *pectoralis major*). There are also osteophytes around the margin of the articular surface of the humeral head.

Figure 3.2.5c: Right proximal humerus from Sk 167B, Castledyke, with robusticity and bone formation on the crest of the greater tubercle. Scale: 5 cm.

Figure 3.2.5d shows an anterior view of the left patella from Sk 159, from Castledyke South, with very robust bone formation on the anterior surface. The patella provides for the insertion of the *quadriceps femoris* muscle, which extends the leg at the knee, flexes the thigh at the hip and is used for actions which require flexion and leg extension such as walking (Stone and Stone, 2000).

Figure 3.2.5d: Anterior view of left patella from Sk 150, Castledyke, with robusticity and bone formation on the proximal margin, anterior surface and distal margin. Scale: 5 cm.

Figure 3.2.5e: Left proximal humerus from Sk 99 134, from the Bamburgh Bowl Hole. A lytic lesion is present at the insertion of the teres major (white arrow). Scale: 5 cm.

Figure 3.2.5e shows an anterior view of the left proximal humerus from Sk 99 134, Bamburgh, with a lytic lesion medial of the bicipital groove, at the insertion of the *teres major*. The *teres major* rotates the arm medially and extends and adducts the arm (Stone and Stone, 2000).

3.2.6 Asymmetry

A series of external measurements were taken from the paired humeri and femora, in order to establish the degree of asymmetry in size between the sides. As discussed in Chapter 1.3, clinical studies have related the dimensions of limb bones to activity levels and body mass during life (Lieberman *et al.*, 2001, Ruff *et al.*, 1994). The majority of studies of bone asymmetry in relation to physical activity analyse cross-sectional geometry of the bone in question, assessed from radiographs or CT scans (see Chapter 1, Section 1.4.4). However, scanning or radiographing large numbers of bones is expensive and time consuming. In this study the aim was to use simple techniques that could be repeated easily and did not require complex equipment, so external measurements of the bones were taken. Although this methodology does not produce the precise picture of cortical bone structure given by CT scans and radiographs, it is still possible to identify asymmetry of size and shape, which can be compared within and between populations. It has been stated that there is a relationship between relatively large external long bone dimensions and high cross sectional geometric values (Larsen, 1997), and therefore the external measurements of the bone should, to some extent, reflect the shape and size of the cortical bone, which in turn is influenced by the action of the musculature.

The measurements taken from the humeri and femora- total length, medio-lateral and antero-posterior diameter and circumference, were intended to explore potential variety of differences in size and shape in each skeletal sample. Bilateral asymmetries in length may reflect loading up to that age of fusion of the epiphysis at skeletal maturity, while asymmetries in the width and shape of the diaphysis are more likely to reflect loading nearer to time of death (Sakaue, 1998). The measurements of diameter and circumference of the humerus and femur were taken at 50% of the length. Figure 3.2.6a shows the location of the measurements taken from the humerus, while figure 3.2.6b shows the location of the measurements taken from the femur.

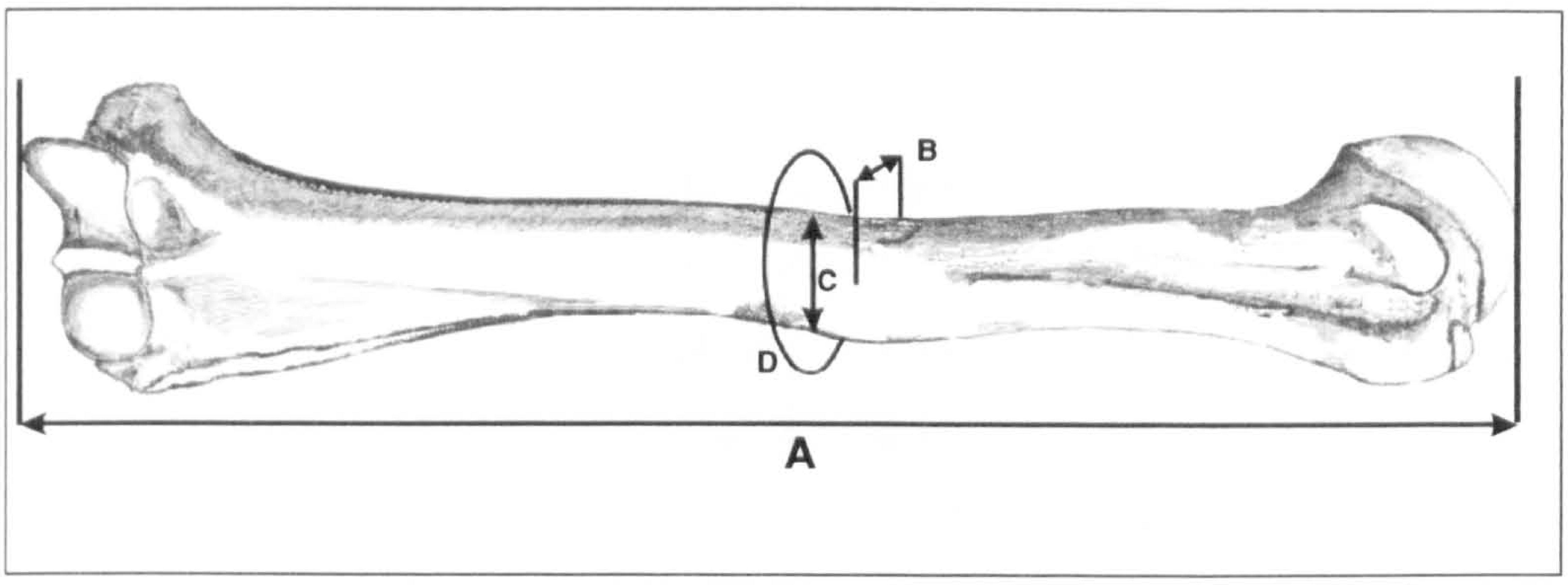


Figure 3.2.6a: The location of the measurements taken from the humerus. A= the total length of the humerus, B = the antero-posterior diameter, C = the medio-lateral diameter and D = the circumference.

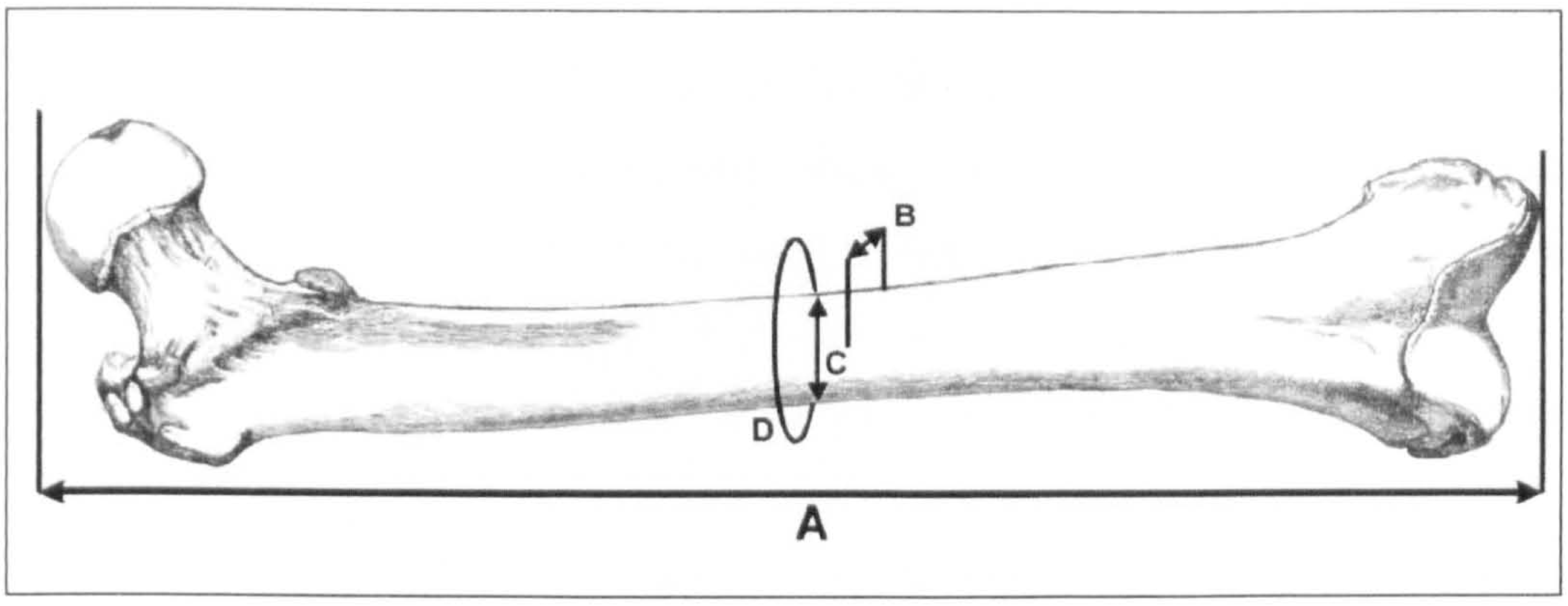


Figure 3.2.6b: The location of the measurements taken from the femur. A= the total length of the humerus, B = the antero-posterior diameter, C = the medio-lateral diameter and D = the circumference.

Measurements were only taken from paired humeri and femora, where one side was not present the other side was also not measured. Due to the state of preservation of the skeletal material it was not possible to take measurements of the length of the humeri and femora in many of the individuals, therefore the length data were not utilised further. In cases where it was not possible to measure the total length, the measurements of the diameter and circumference were taken, if applicable. Measurements of total length were taken to the nearest 0.5 mm using an osteometric board; measurements of antero-posterior and medio-lateral diameter were taken using a Mitutoyo Digimatic sliding calliper with a resolution of 0.01mm, an instrumental error of +/- 0.02mm and repeatability of 0.01mm. Measurements of circumference were taken to the nearest 1mm using a waxed canvas hand tape, the same tape being used for all the skeletal samples. All measurements were taken three times and the average of these three measurements was recorded on the recording form.

3.2.7 Controls

Examining the whole body for changes that may be associated with physical activity provides some elements of control in itself; conditions that may affect the patterns of changes, such as DISH, trauma, and neoplastic conditions could be identified and the affected skeletons were excluded. Analysing the skeletal material for age allows increasing age to be excluded as a factor in the aetiology of conditions such as OA and enthesopathy- if these changes are seen in younger individuals without evidence for trauma, it is more likely that they are the result of high levels of physical activity.

In order to assess the accuracy and repeatability of the methods used, 10 skeletons from each of the Castledyke South and Bamburgh samples were re-examined without reference to the first set of results. When the results for these repeated analyses were compared with the findings from the first examinations, although there was some variation in the measurements of the paired humeri and femora, the differences in the degree of asymmetry (the difference between the measurements from the right and left sides) were not statistically significant, in either the humeri or femora, using paired t tests. The results of these tests are shown in Table 3.2.7a.

	Castledyke			Bamburgh		
	Original	Repeat	p value	Original	Repeat	p value
Humerus M/L	1.7	1.7	0.5	1.2	1.2	0.5
Humerus A/P	0.6	0.6	0.5	1.1	1.1	0.4
Humerus Circ	2.6	2.9	0.09	3.5	3.4	0.2
Femur M/L	0.9	0.9	0.3	1.5	1.5	0.5
Femur A/P	1.2	1.2	0.5	1.0	1.1	0.2
Femur Circ	2.3	2.2	0.3	2.5	2.3	0.1

Table 3.2.7a: Comparison of the mean absolute asymmetries (in mm) calculated from the original and repeat measurements of the humeri and femora from Castledyke and Bamburgh. The results of paired t-tests, used to identify any differences between the measurements are also given.

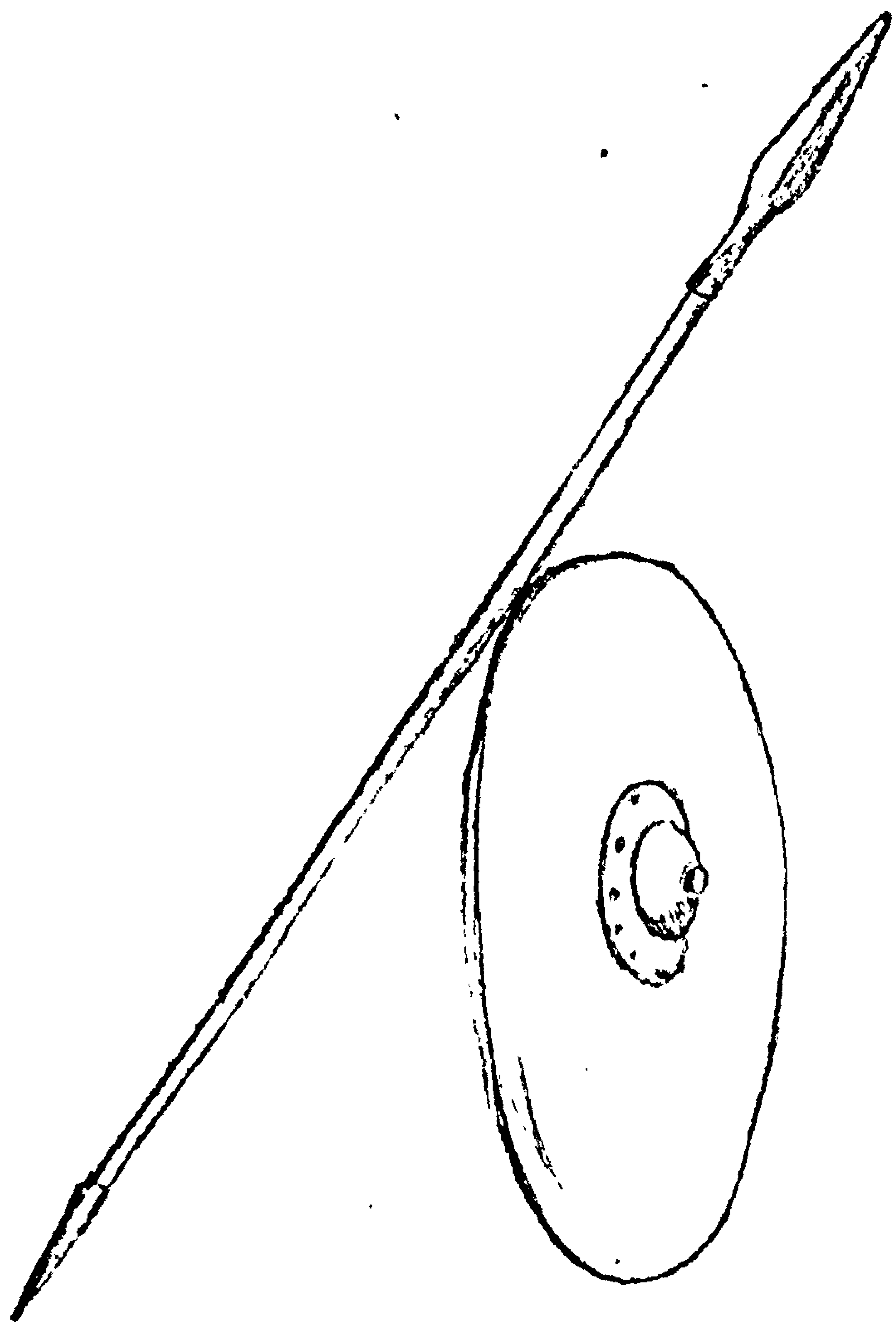
The results for the analysis of joint disease and enthesopathies were the same in 99% of the repeated results, and for the Schmorl's nodes the results were the same in 100% of the repeated analyses.

3.3: Data analysis

MS Access databases were created to organise and evaluate the data from each site. Information regarding the osteological analysis, associated grave goods and burial practices for each individual were entered into the database. Data were also entered into MS Excel spreadsheets for analysis. Where sample sizes were small, weighted means were calculated, using the number of incidences of the value as the weight, in order to account for potential bias due to outliers in the data. Statistical analysis of the data using Chi squared tests and analysis of variance (ANOVA) tests was undertaken using MS Excel, which was also used to produce graphs and tables. Chi squared was used to analyse ordinal data such as numbers of occurrences of a condition, or the number of individuals affected, to identify occasions where the number of occurrences varied from the number that might be expected. Single factor ANOVA tests were used to analyse numerical data; the mean numbers of occurrences of conditions and the variation in the asymmetry data between groups. The results of these statistical tests were considered to be significant where the p value was equal or less than 0.05.

The following Chapter will give the results of this study; the age and sex profile and burial practices seen at each site will be reported, followed by the results for each of the conditions examined as markers of activity related stress, in each of the age and status groups in each of the skeletal samples.

Chapter Four: Results



4: Results

4.1: Age and Sex

4.1.1: Age

As many of the conditions used to examine patterns of physical activity are also associated with advancing age and degeneration in the skeleton, as discussed in Section 1.4, it is important to identify the proportions of individuals in each age group in each skeletal sample. If one sample has a higher proportion of older individuals than the others, it is possible that this variation may affect the frequencies of conditions such as enthesopathy and osteoarthritis in the sample.

Age can also be a significant factor in the construction and achievement of social status, and hence the treatment of individuals in death, as has been discussed by Gowland (2002) as can sex, and consequently patterns of social status within and between samples may be affected by the distribution of age-at-death. The following Table shows the percentages of skeletons that were examined in each of the age groups defined in Chapter 3, in the selected samples.

Age	Castledyke	Norton Mill Lane	Bamburgh	Norton Bishopsmill	Total no
1 Young	24.4 (21)	29.4 (15)	15 (6)	20 (8)	50
2 Young/ middle	18.6 (16)	23.5 (12)	7.5 (3)	12.5 (5)	36
3 Middle	19.8 (17)	27.5 (14)	27.5 (11)	32.5 (13)	55
4 Older	31.4 (27)	13.7 (7)	47.5 (19)	30 (12)	65
5 Adult	5.8 (5)	5.9 (3)	2.5 (1)	5 (2)	11
Total no	86	51	40	40	

Table 4.1.1: Percentage of individuals, and numbers of individuals (in brackets), from each age group in the four samples. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

All of these individuals were sufficiently well preserved for some or all of the joints or entheses to be examined for changes, but in some cases the vertebral columns were not present or not sufficiently well preserved to allow the vertebral surfaces to be examined for the presence of Schmorl's nodes, and in some individuals the humeri and femora were not present or sufficiently well preserved for measurements of asymmetry to be made.

When examined using a chi-squared test, the differences in the proportion of the "Older" age groups between the populations was significant with a p value of 0.04. The sample from Bamburgh had a higher proportion of "Older" individuals than the other samples, and it is possible that this affected the statistical analysis. When the data from Bamburgh was excluded, the differences between the other age groups were not statistically significant.

4.1.2: Sex

A "normal" population which is not affected by pressures selecting for one sex or the other (such as warfare that took place away from "home", thus reducing the proportion of males in an otherwise typical cemetery population, or sites where location of burials within the cemetery is influenced by sex) tends to have a 1:1 ratio of males to females. Where this ratio is not seen it may be due to differential preservation of the skeletal material, or some pressure upon the population leading to this variation, a pressure which may also affect patterns of abnormal variation observed within the population. However, as osteological methods of identifying biological sex are not 100% accurate (Mays, 2000) and, in some cases, it is not possible to identify the sex of individuals due to poor preservation or ambiguous anatomical features, it is quite rare to see a 1:1 ratio of males to females in an archaeological sample. As discussed in Chapter 3.2, issues of the preservation of skeletal material and incomplete excavation of cemetery sites can also lead to abnormal ratios of males to females.

The following Table shows the distributions of females, males and adult individuals of unknown sex in each of the samples in this study. As the numbers of individuals at these sites are relatively small, the individuals that were sexed as possible female or possible male were not considered as separate categories from those that were sexed with more confidence, so possible males and possible females were added to the male and female categories.

Sex	Castledyke	Norton Mill Lane	Bamburgh	Norton Bishopsmill	Total no
Female	51.2 (44)	37.3 (19)	42.5 (17)	42.5 (17)	97
Male	44.2 (38)	56.9 (29)	57.5 (23)	55 (22)	112
Unknown	4.7 (4)	5.9 (3)	0 (0)	2.5 (1)	8
Total no	86	51	40	40	

Table 4.1.2: Percentage and numbers (in brackets), of females, males and adult individuals of unknown sex in each of the skeletal samples.

Other than at Norton Mill Lane, where the percentage of individuals of unknown sex is the highest of all the samples, the proportions of females to males are relatively even. The differences in the proportions of males, females and individuals of unknown sex were not statistically significant using a chi-squared test.

4.1.3: Presentation of Results

In the following sections the results of the examination of the skeletal samples from the four sites are presented, as follows:

- Section 4.2: Burial practices at each site according to sex and age.
- Section 4.3: Prevalence of osteoarthritis from each of the skeletal samples, according to sex, age and status groups.
- Section 4.4:Prevalence of enthesopathies according to sex, age and status groups.
- Section 4.5: Prevalence of Schmorl's nodes according to sex, age and status groups.
- Section 4.6: Asymmetry of the paired humeri and femora according to sex, age and status groups.

At the end of each section the results are summarised, and any patterns of involvement that may be due to differences in social status are highlighted.

4.2: Burial Practices

The relative depth of graves within Early Medieval cemeteries has been used as an indicator of social status, as discussed in section 2.1.3. Using the data contained within the site reports or archives, the average depth of graves was compared between individuals buried with and without artefacts at the four sites.

While there was no difference between the depths of burials at Castledyke, there was some variation in the depth of burials at Mill Lane, with the graves cuts of individuals buried without grave goods being on average shallower than those of individuals with grave goods, but not significantly so (mean depth of graves with artefacts - 0.33 m, no artefacts – 0.25 m, ANOVA p= 0.3). The burials of males with weapons were the deepest on average (0.45 m). This variation suggests that depth of burial may have been another means of showing the social status of the individual being buried, but only in the case of the weapon burials.

At Bamburgh, individuals who were buried without any artefacts were significantly shallower than those with artefacts (mean depth of graves with artefacts – 0.31 m, mean depth of graves without artefacts – 0.20 m, ANOVA p=0.009), and although this difference may be an artefact of poor preservation at this site, it is also possible that this difference represents a further variation in burial practice associated with social status.

At Norton Bishopsmill there was little variation in the depth of the burials, with most being shallow and the deepest only being around 0.3 m below the topsoil. As at Castledyke there was no difference in the mean depth of the graves between those buried with and without artefacts.

4.2.1: Burial Practices- Sex

As described in Chapter 3, at Castledyke South and Norton Mill Lane, burial practice was examined using a method of examining the types and quantities of grave goods associated with sex and concepts of social status. Table 4.2.1a shows the percentage of males and females in each of the four artefact groups at Castledyke; the number of individuals of each sex in the artefact group is given in brackets.

Artefact Group	% in each Group Female	Male	Total no.
Group 1	44 (11)	48 (12)	23
Group 2	45 (15)	48 (16)	31
Group 3	0 (0)	100 (8)	8
Group 4	90 (18)	10 (2)	20
Total no.	44	38	82

Table 4.2.1a: Percentage and number of males and females in the artefact groups at Castledyke; Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.2.1a shows the percentage of females, males and individuals of unknown sex in each of the burial artefact groups at Castledyke. From this Figure, and from Table 4.2.1a, it is apparent that there were variations in burial practice associated with sex; Group 3 was exclusively male, while the percentage of males in Group 4 was very small. In these artefact groups it appears that sex was a factor for the choice of grave goods, but for Groups 1 and 2 biological sex was not a factor in the choice of items placed with the burial.

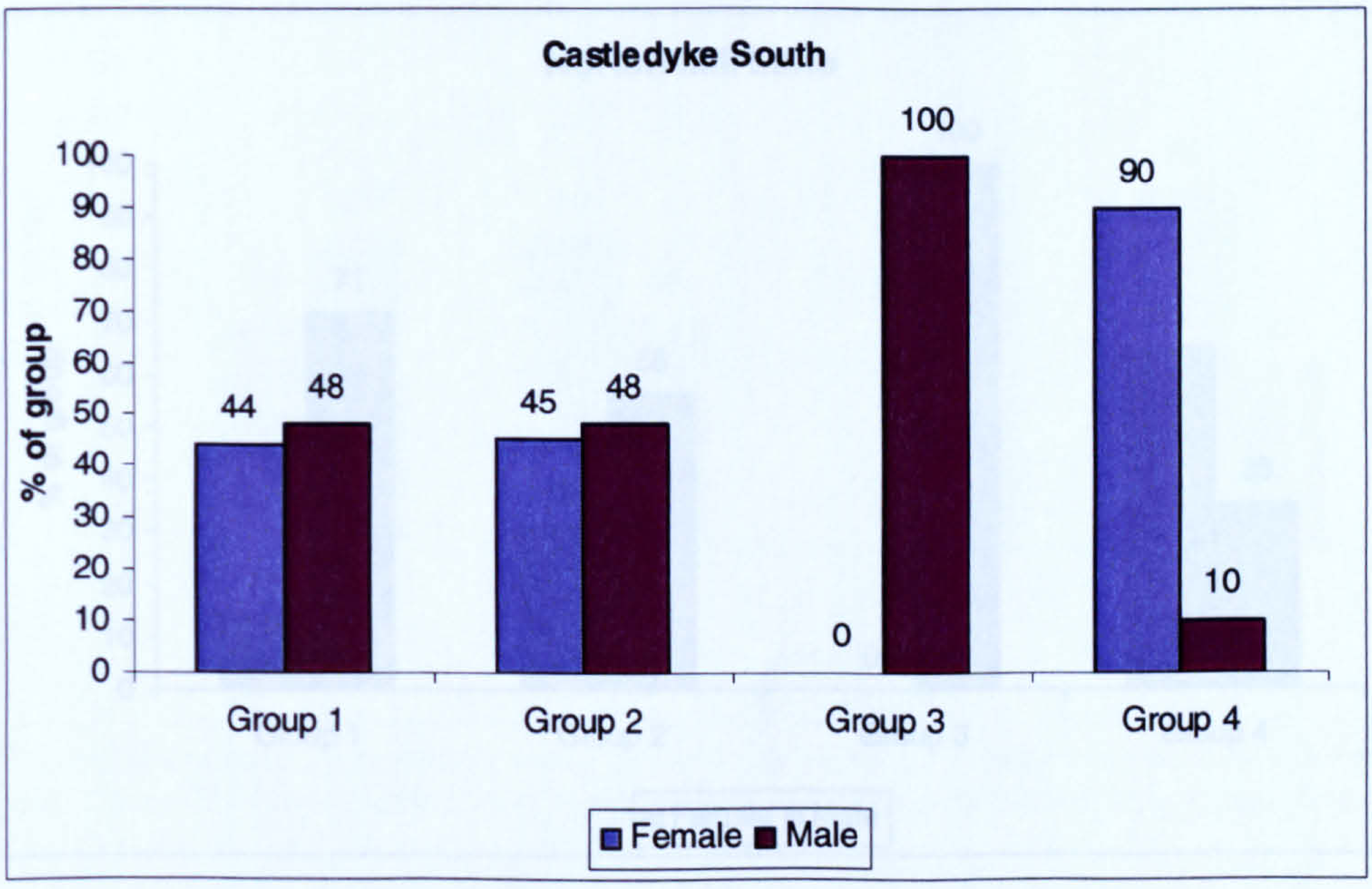


Figure 4.2.1a: The percentages of males and females in each artefact group from Castledyke South. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Table 4.2.1b shows the percentage of males and females in each of the four artefact groups at Norton Mill Lane; the number of individuals of each sex in the artefact group is given in brackets.

Artefact Group	% in each Group Female	Male	Total no.
Group 1	14 (1)	71 (5)	6
Group 2	31 (5)	56 (9)	14
Group 3	0 (0)	100 (8)	8
Group 4	65 (13)	35 (7)	20
Total no.	19	29	48

Table 4.2.1b: Percentage and number of males and females in the artefact groups from Norton Mill Lane; Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.2.1b shows the percentage of females, males and individuals of unknown sex in each of the burial artefact groups at Norton Mill Lane. As table 4.2.1b and figure 4.2.1b show, at Norton Mill Lane the percentage of males in Group 4 was higher than that seen at Castledyke, and the percentage of females in Groups 1 and 2 was much higher at Norton. As at Castledyke, Group 3 was entirely composed of males. The number of individuals in Group 1 was considerably smaller at Norton Mill Lane than at Castledyke.

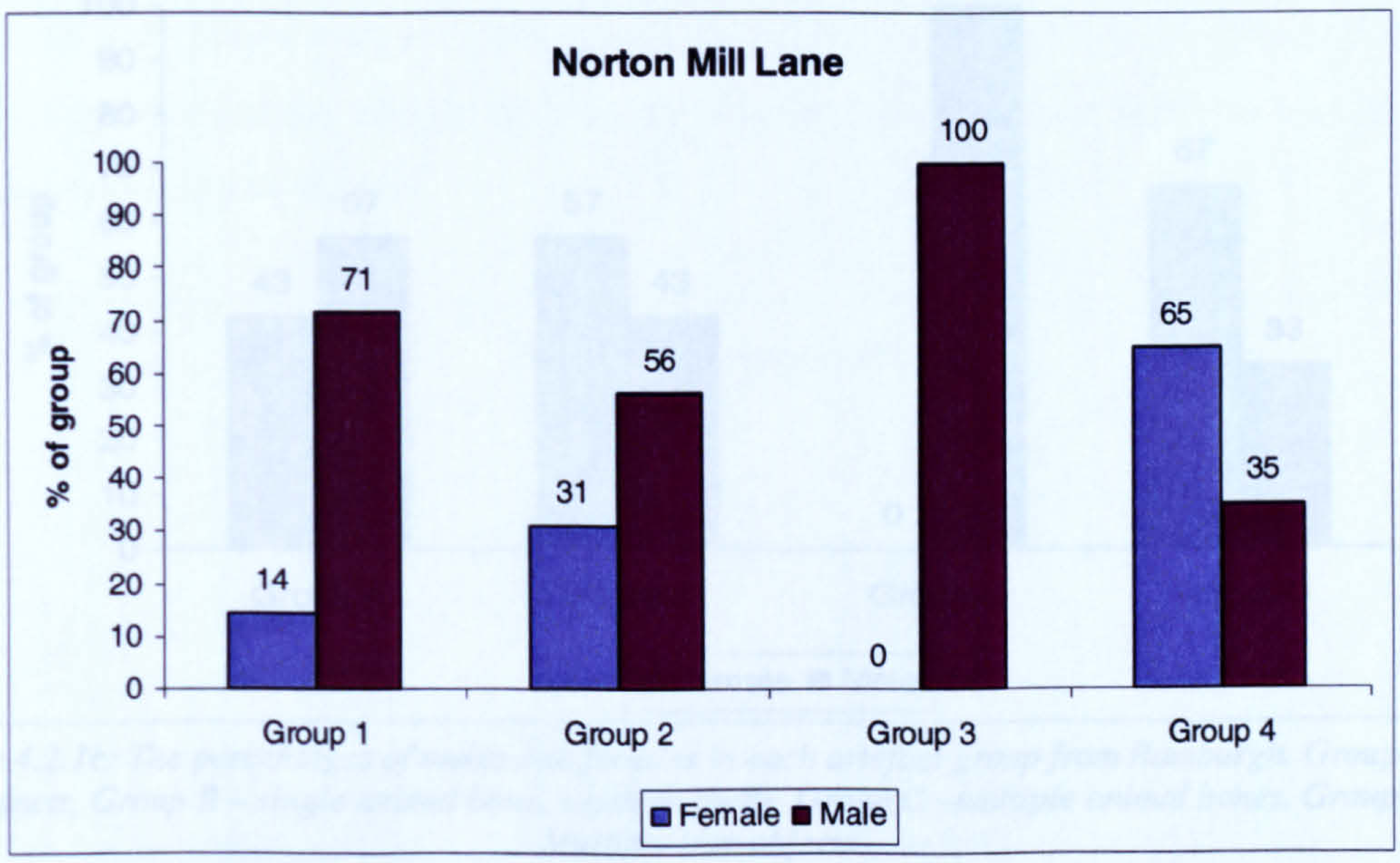


Figure 4.2.1b: The percentages of males and females in each artefact group from Norton Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

At Bamburgh and Norton Bishopsmill, the criteria used to divide the skeletons into artefact groups were different to those applied at Castledyke and Norton Mill Lane, as discussed in

Chapter 3. Table 4.2.1c shows the percentage of males and females in each artefact group at Bamburgh, and the number of individuals in each group.

	% in each group		
	Female	Male	Total no
Group A	43 (9)	57 (12)	21
Group B	57 (4)	43 (3)	7
Group C	0 (0)	100 (6)	6
Group D	67 (4)	33 (2)	6
Total no	17	23	40

Table 4.2.1c: Percentage and number of males and females in the artefact groups from Bamburgh, Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

This table, and Figure 4.2.1c, show that the majority of individuals from Bamburgh were buried without artefacts of any kind, and that sex was clearly a factor for burial with deliberately placed animal bones as the only burial artefacts.

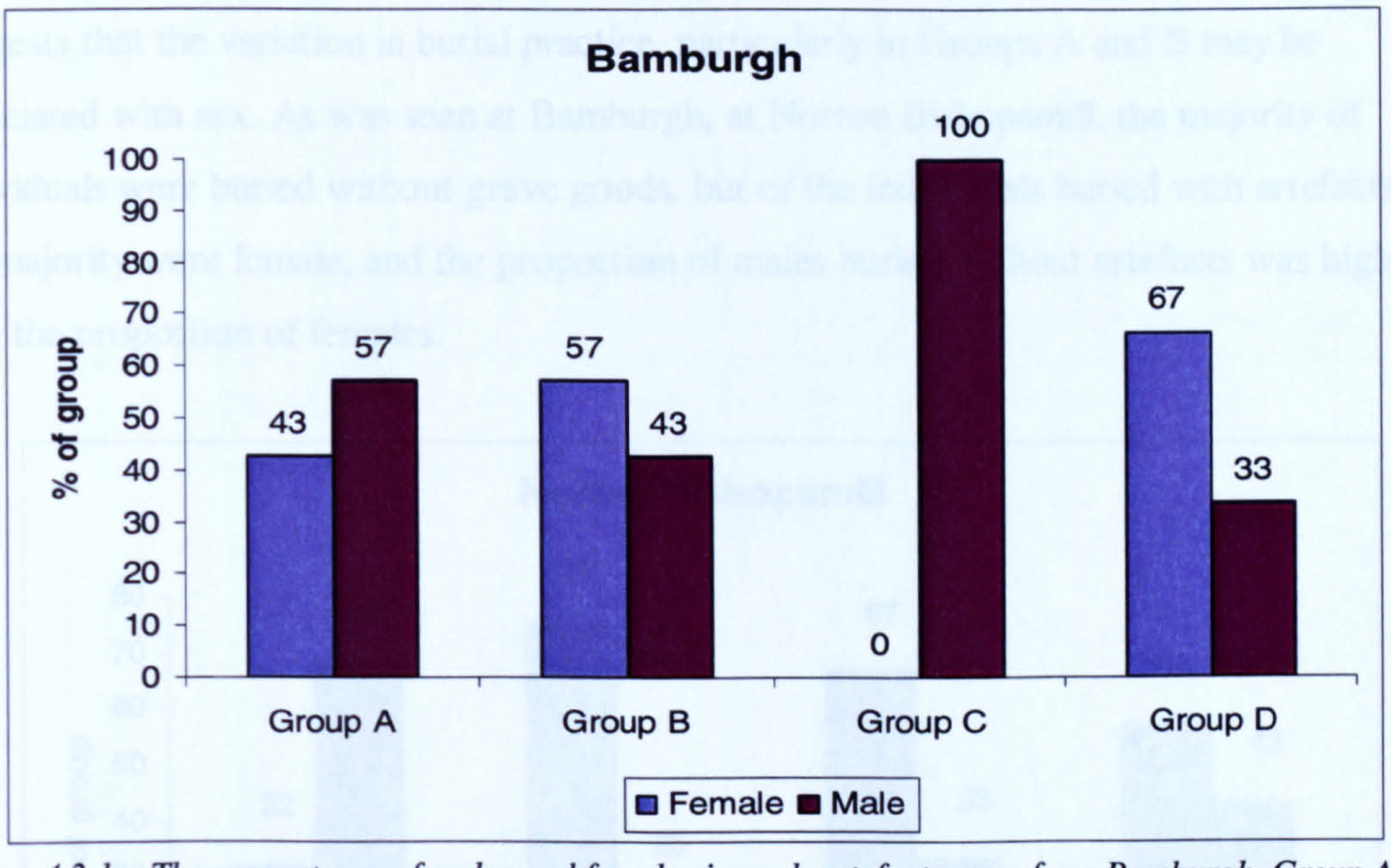


Figure 4.2.1c: The percentages of males and females in each artefact group from Bamburgh. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

As was seen at Castledyke, the proportion of males and females burials without grave goods was quite similar, suggesting that biological sex was not a factor for unfurnished burials.

At Norton Bishopsmill the sample was also divided into four groups based upon the type of artefacts associated with each of the burials although, as discussed in Chapter 3, the types of artefacts associated with burials were somewhat different to those seen at Bamburgh and very different to the burial practices at Castledyke and Norton Mill Lane. Table 4.2.1d shows the percentage of males and females in each of the four artefact groups. The number of individuals in each group is given in brackets.

	% in each group		
	Female	Male	Total no
Group A	32 (8)	68 (17)	25
Group B	75 (3)	25 (1)	4
Group C	67 (2)	33 (1)	3
Group D	57 (4)	43 (3)	7
Total no.	17	22	39

Table 4.2.1d: Percentage and number of males and females in the artefact groups from Norton Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Figure 4.2.1d shows the distribution of the sexes in each of the four artefact groups, and suggests that the variation in burial practice, particularly in Groups A and B may be associated with sex. As was seen at Bamburgh, at Norton Bishopsmill, the majority of individuals were buried without grave goods, but of the individuals buried with artefacts, the majority were female, and the proportion of males buried without artefacts was higher than the proportion of females.

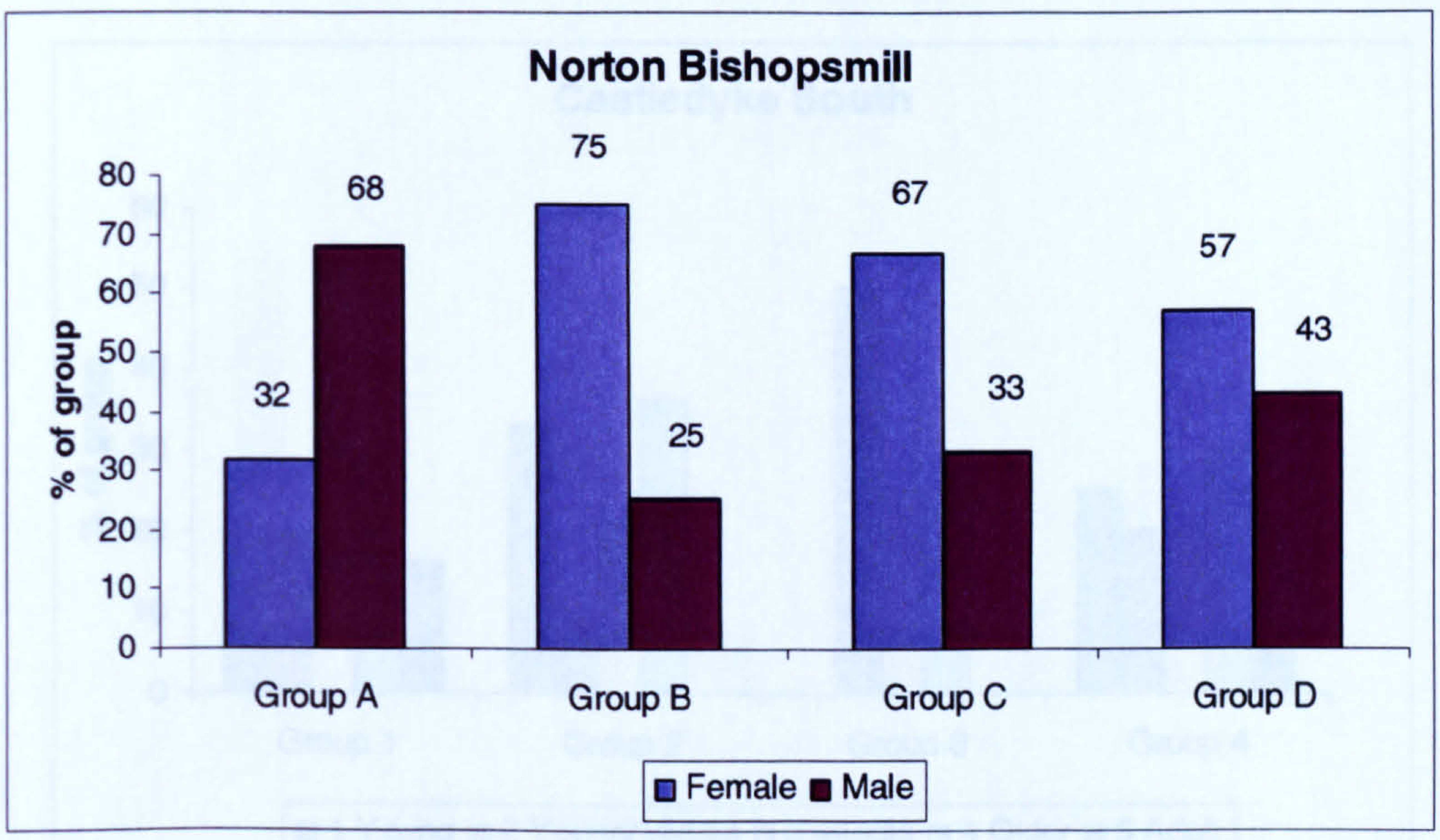


Figure 4.2.1c: The percentages of males and females in each artefact group from Norton Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

4.2.2: Burial Practices – Age

In order to establish whether age at death was a factor that influenced the types of artefacts that were associated with individuals at each of the sites, the percentage of individuals from each age group in each of the artefact groups was examined. As the changes examined as markers of activity-related stress may also be associated with advancing age (see section 1.4) it was important to be aware of potential differences in the age-at-death of the individuals in the artefact groups.

Table 4.2.2a shows the percentage of individuals from each of the age groups in each of the four burial artefact groups at Castledyke South. The number of individuals in each of the age groups is given in brackets.

	Young	Young/Middle	Middle	Older	Adult	Total no
Group 1	20 (5)	20 (5)	16 (4)	28 (7)	16 (4)	25
Group 2	33 (11)	9 (3)	21 (7)	36 (12)	0 (0)	33
Group 3	0 (0)	50 (4)	25 (2)	25 (2)	0 (0)	8
Group 4	25 (5)	20 (4)	20 (4)	30 (6)	5 (1)	20
Total no	21	16	17	27	5	86

Table 4.2.2a: Percentage of individuals from each age group in each of the artefact groups. The number of individuals is given in brackets; Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

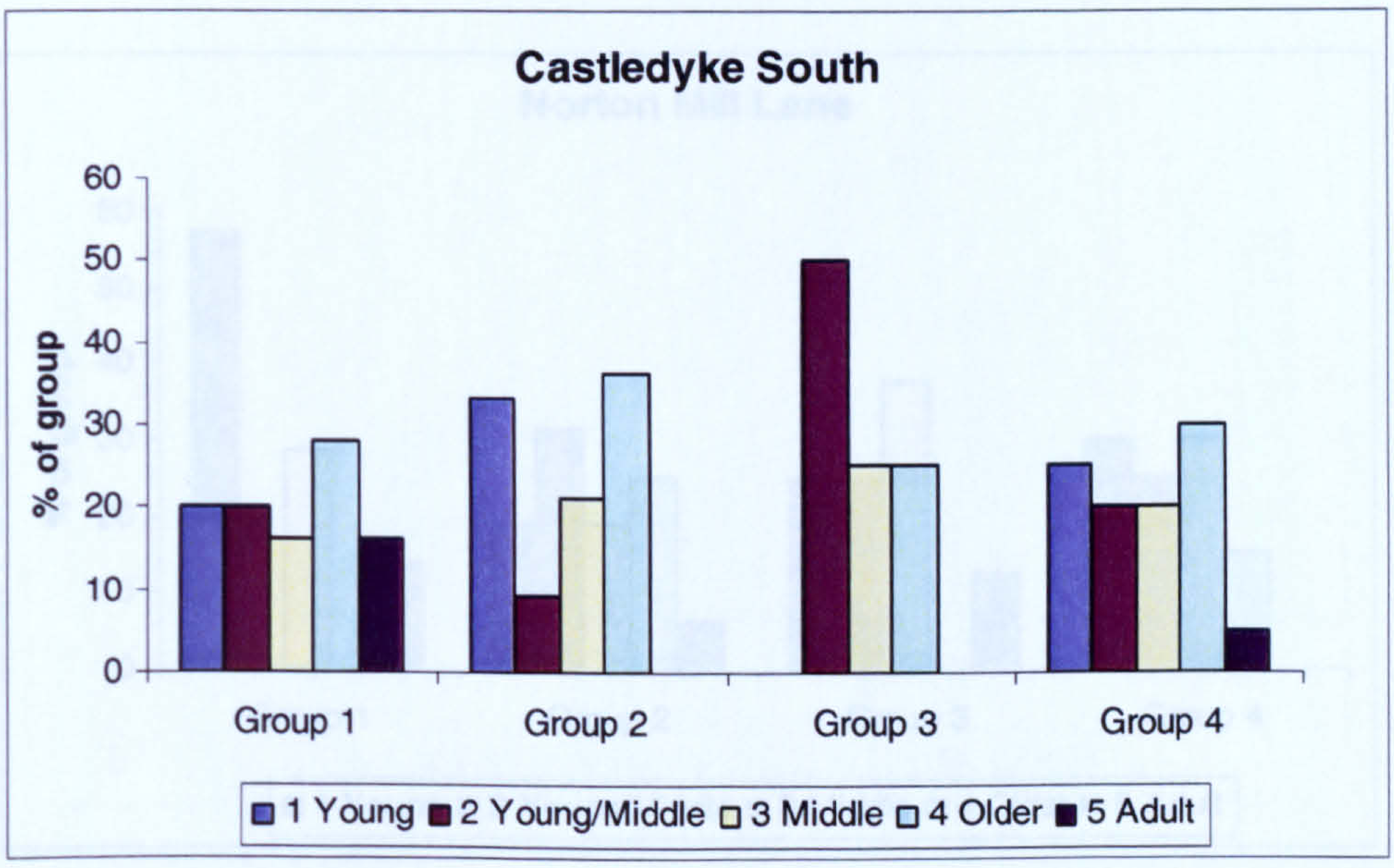


Figure 4.2.2a: Percentage of individuals from each age group in each Artefact Group at Castledyke South..

These results show that there was variation in the percentage of individuals from each age group in the different artefact groups; there were no Young adults in Group 3, and the percentage of Young/Middle adults was low in Group 2. There were Older adults in all the artefact groups, but the highest percentage was present in Groups 1 and 2. The distribution of Middle aged adults was similar across all the artefact groups.

Table 4.2.2b, shows the percentage of individuals from each of the age groups in each of the burial artefact groups at Norton Mill Lane. The number of individuals in each of the age groups is given in brackets.

	Young	Young/Middle	Middle	Older	Adult	Total no
Group 1	57 (4)	0 (0)	29 (2)	0 (0)	14 (1)	7
Group 2	19 (3)	31 (5)	19 (3)	25 (4)	6 (1)	16
Group 3	25 (2)	25 (2)	38 (3)	0 (0)	13 (1)	8
Group 4	30 (6)	25 (5)	30(6)	15 (3)	0(0)	20
Total no.	15	12	14	7	3	51

Table 4.2.2b: Percentage of individuals from each age group in each of the artefact groups. The number of individuals is given in brackets; Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.2.2b shows the percentage of individuals from each age group in each artefact group at Norton Mill Lane.

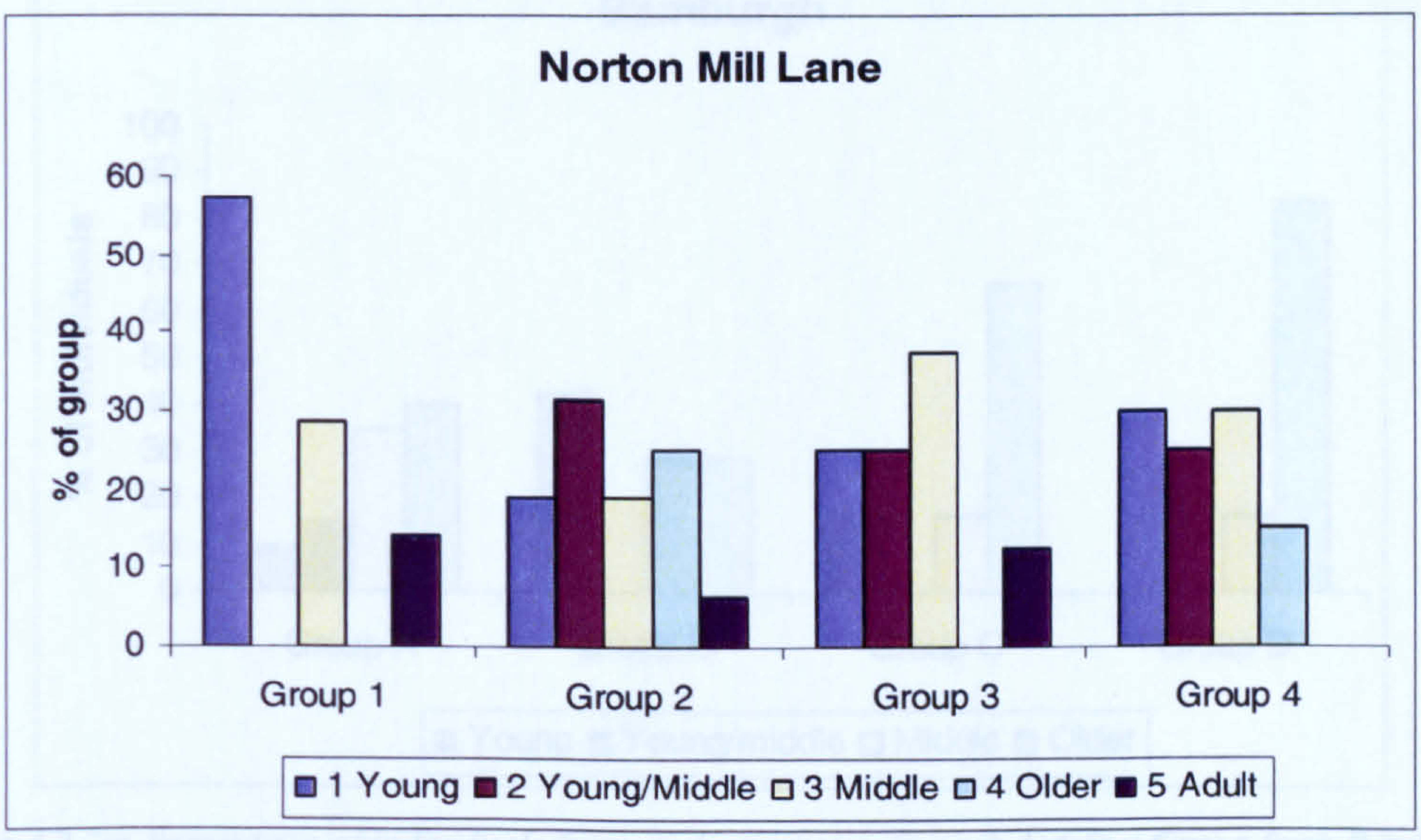


Figure 4.2.2b: Percentage of individuals from each age group in each Artefact Group from Norton Mill Lane.

Group 4 was the only group to have individuals from all known age bands. Group 1 had the highest percentage of Young individuals, while Group 2 had the highest percentage of Older adults of all the groups. Group 3 had the highest percentage of Middle aged adults, but no adults that were over the age of 41 at death (Older age group). The distribution of adults from different age groups between the artefact groups was different to that seen at Castledyke, suggesting that, despite the apparent similarities in the artefact groups there may have been differences in the associations between burial practices and age-at-death between the two sites.

At Bamburgh, there seem to have been some associations between age at death and burial practice; table 4.2.2c shows the number and percentage of individuals from each of the age groups that were present in each artefact group.

	Young	Young/Middle	Middle	Older	Total no
Group A	10 (2)	15 (3)	35 (7)	40 (8)	20
Group B	43 (3)	0 (0)	29 (2)	29 (2)	7
Group C	17 (1)	0 (0)	17 (1)	67 (4)	6
Group D	0 (0)	0 (0)	17(1)	83 (5)	6
Total no	6	3	11	19	39

Table 4.2.2c: Percentage of individuals from each age group in each of the artefact groups. The number of individuals is given in brackets; Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

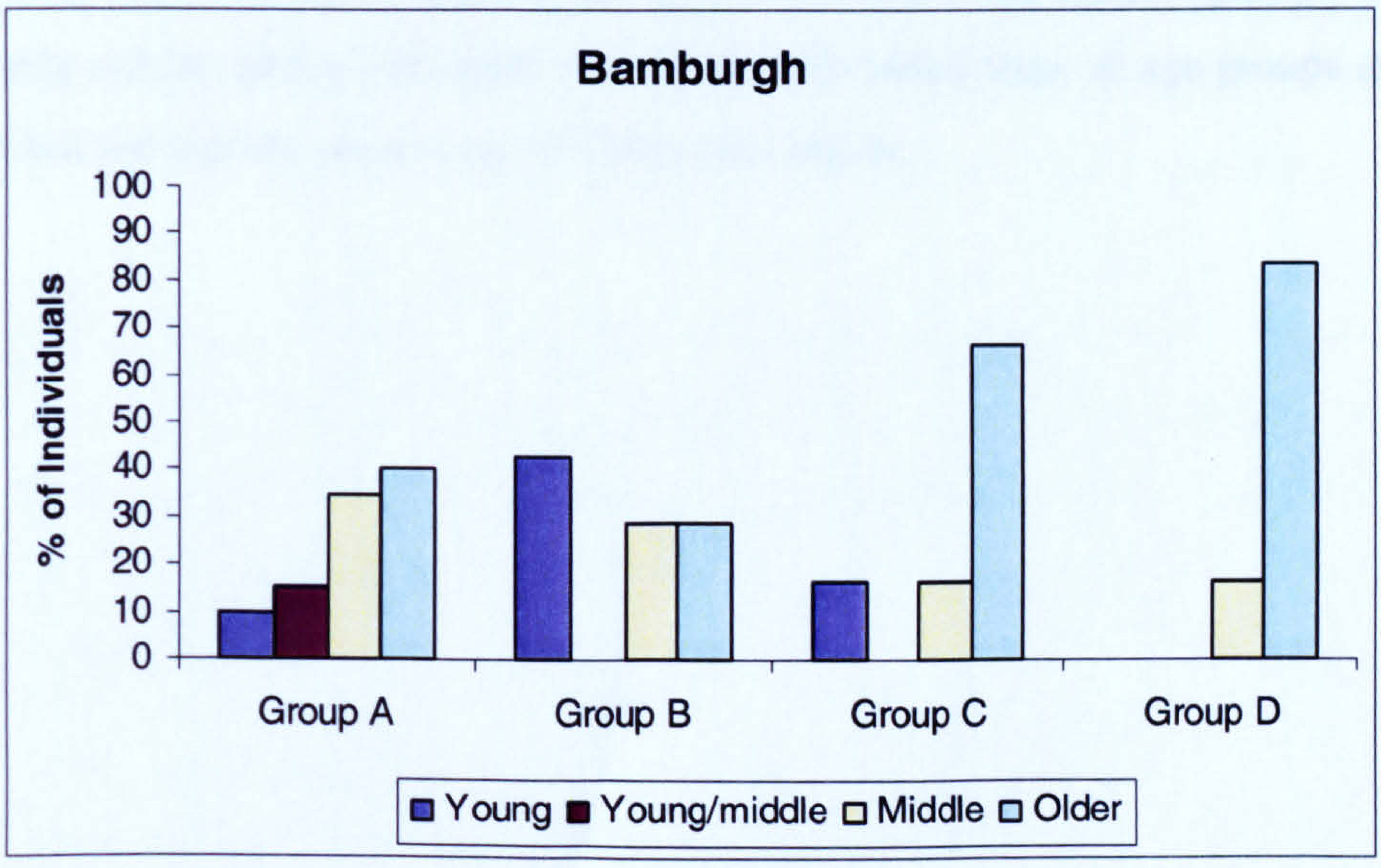


Figure 4.2.2c: Percentage of individuals from each age group in each Artefact Group from Bamburgh.

Group A, the individuals without artefacts, was the only group to include individuals from all age groups, and Group D consisted entirely of Middle aged and Older individuals. As has been mentioned above, Bamburgh had the highest proportion of Older adults of all four sites, so it is not surprising that the percentage of Older individuals appear to be high in all artefact groups. However, the high proportion of Older adults in Groups C and D is striking and suggests that age may be a factor for burial with animal bones or iron objects at Bamburgh.

Table 4.2.2d shows the percentage of individuals from each age group in each of the four burial artefact groups at Norton Bishopsmill. This table shows that the age distribution between the artefact groups was quite similar

	Young	Young/middle	Middle	Older	Total no.
Group A	22 (5)	13 (3)	39 (9)	26 (6)	23
Group B	25 (1)	25 (1)	25 (1)	25 (1)	4
Group C	25 (1)	0 (0)	50 (2)	25 (1)	4
Group D	14 (1)	14 (1)	14 (1)	57 (4)	7
Total no.	8	5	13	12	38

Table 4.2.2d: Percentage of each age group in each artefact group. The number of individuals in each group is shown in brackets. Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Figure 4.2.2d shows the distribution of age groups in each of the artefact groups; Group C was the only artefact group which did not include individuals from all age groups and Group D had the highest percentage of Older individuals.

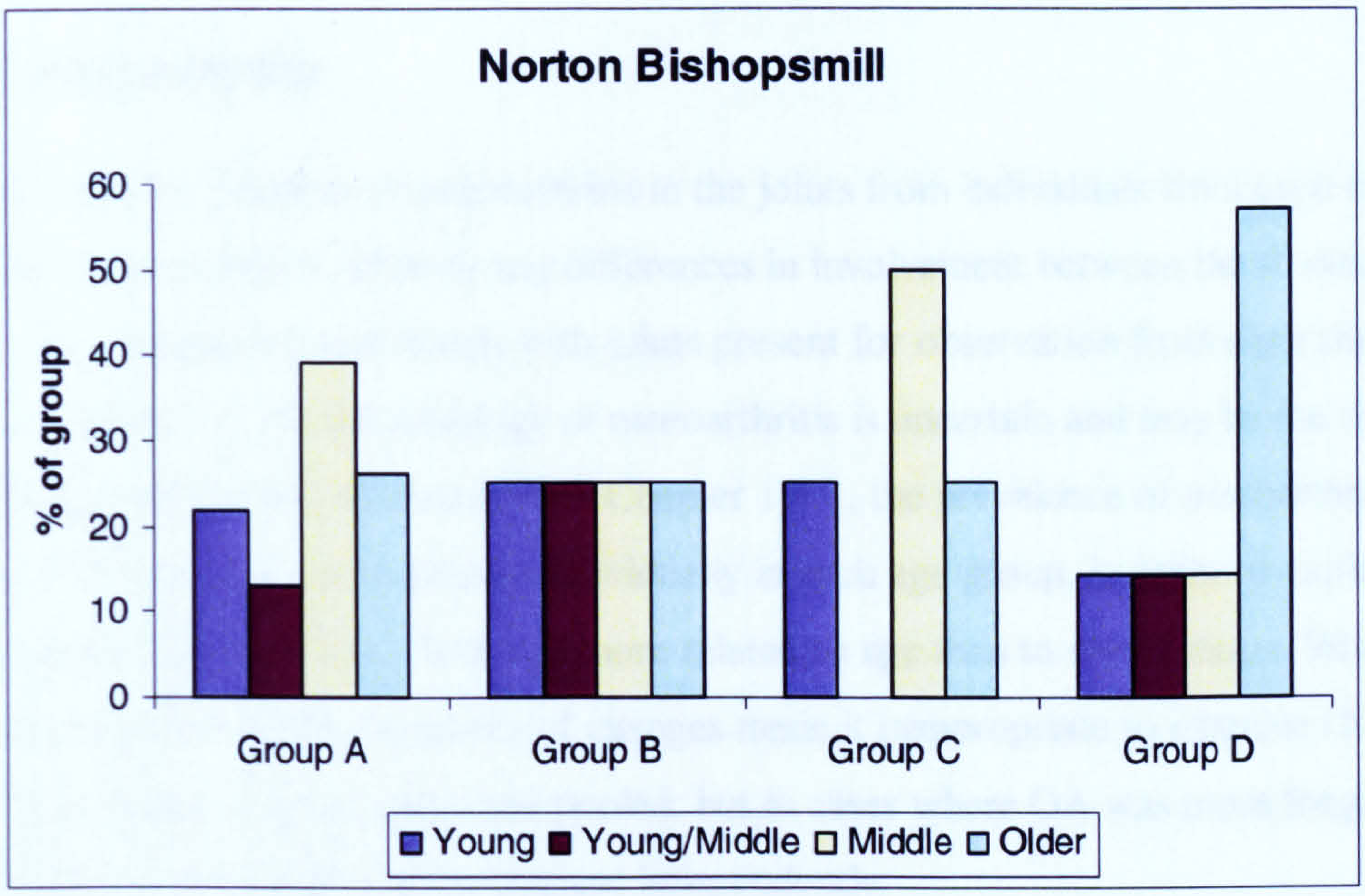


Figure 4.2.2d: Percentage of individuals from each age group in each Artefact Group at Norton Bishopsmill

These results suggest that as at Bamburgh there may have been an association between age and burial practice at Norton Bishopsmill, with older individuals being more frequently associated with more complex burial practice, in this case, iron objects and coffin fittings.

Summary

- Age and Sex: The proportion of Older individuals was highest at Bamburgh, but there was not significant variation between the age profiles at the other three sites. The variation in the proportion of males and females was not significant.

- Burial Practice: At Castledyke, Mill Lane and Bamburgh, sex was a factor in burial practice in some of the groups, but less so at Bishopsmill. Age had more of an impact upon burial practice at Bamburgh and Bishopsmill than at Castledyke and Mill Lane, particularly in Groups C and D.

4.3: Osteoarthritis

In this section the patterns of osteoarthritis in the joints from individuals from each of the four sites are examined to identify any differences in involvement between the artefact groups. The numbers of individuals with joints present for observation from each site are given in Appendix 2. As the aetiology of osteoarthritis is uncertain and may be the result of a combination of factors, as discussed in Chapter 1.4.1, the prevalence of osteoarthritis and possible osteoarthritis was examined individually in each age group, in order to explore whether degeneration of the joints was more related to age than to social status. Where small sample size and low frequency of changes made it inappropriate to examine OA and possible OA separately the data were pooled, but in cases where OA was more frequent, the two grades of changes were examined independently.

4.3.1: Castledyke South

Of the total sample of 86 individuals with joint surfaces present from Castledyke, 63 individuals (73%) had porosity and osteophytes of one or more joint surfaces, of which 27 individuals (31.4% of the total sample) also had eburnation in one or more joints.

Tables showing the number and percentage of each joint surface observed, and the number and percent affected by porosity and osteophytes (?OA), porosity, osteophytes and eburnation (OA) on the left and right sides of the upper and lower limbs are presented in Appendix 2.1. In the upper limb, the percentage of joints observed with porosity and osteophytes was greater on the right side in all joints, except the proximal radius. Other than in the distal radius, the percentage of joints observed with eburnation was equal to or greater than the percentage seen on the left side.

In the lower limb, the percentage of right side joints showing porosity and osteophytes was greater than the percentage seen in the left side, in the distal femur, patella, proximal and distal tibia and distal femur, but in the other joints the percentage of possible OA was greater on the left side. Where eburnation was observed, the percentage of right side joints affected was greater than the percentage of left side joints in the acetabulum and patella. In the femoral head and distal tibia the percentage of eburnation observed was equal for both sides, while in the distal femur, proximal tibia and distal fibula the right side was more affected by eburnation.

Table 4.3.1a shows the number of individuals with joints present of each sex, the average number of functional joints (see Section 3.2.4) present for examination in the upper and lower limbs, and the average number affected by osteoarthritis and possible osteoarthritis. The number of joints observed from each sex is given in brackets.

Sex	No. of Sk	Upper Limb Present	Upper Limb OA	Upper Limb ?OA	Lower Limb Present	Lower Limb OA	Lower Limb ?OA
Female	44	3.7 (139)	0.2 (9)	1.1 (42)	4.8 (213)	0.2 (10)	2.1 (94)
Male	37	4 (141)	0.5 (16)	1.8 (63)	5.1 (187)	0.3 (10)	2.4 (89)

Table 4.3.1a: The number of females and males with joints present for observation and the average number of joints present, with OA and with possible OA in the upper and lower limbs. The number of joints present is given in brackets.

In the upper limb and lower limbs, the average number of males with joints affected by osteoarthritis and possible osteoarthritis was higher than the average number of joints from females, although these differences were not statistically significant (ANOVA upper limb OA p=0.1, ?OA p=0.08; lower limb OA p= 0.7, ?OA p= 0.5).

i) Osteoarthritis, Age and Sex

Table 4.31b shows the percentage of joint surfaces from both sides of the upper and lower limbs affected by osteoarthritis, possible osteoarthritis and the percentage that were not affected (None) in females and males from each of the age groups in the Castledyke South sample. The number of joints with osteoarthritis, possible osteoarthritis, no changes and that were not present are given in brackets. The greatest percentage of joints affected by osteoarthritis was seen in the Older individuals, and the percentage of possible osteoarthritis increased with age in both males and females.

Age Group	Female OA	Female ?OA	Female None	Male OA	Male ?OA	Male None
Young	2 (4)	2 (5)	56 (124)	0.3 (1)	2 (6)	39 (130)
Young/ Middle	1 (3)	15 (32)	42 (91)	3 (5)	14 (26)	30 (54)
Middle	2 (4)	21 (41)	49 (96)	2 (5)	27 (65)	39 (93)
Older	3 (11)	31 (99)	38 (123)	3 (12)	36 (130)	29 (104)
Adult	0 (0)	16 (12)	39 (29)	0 (0)	17 (5)	23 (7)

Table 4.3.1b: The percentage of joints from both sides of the upper and lower limbs, in each age group affected by osteoarthritis (OA), possible osteoarthritis (?OA), and not affected from females and males. The number of joints is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

The variation seen in the percentage of joint surfaces with osteoarthritis between the age groups amongst the females was not statistically significant (chi squared p=0.2), but in males the p value was 0.05, suggesting that there was a significant relationship between osteoarthritis and age in males. In contrast, the results for possible osteoarthritis produced p values of less than 0.01 for both sexes, suggesting that the changes associated with possible OA increased significantly with increasing age. These results suggest that possible osteoarthritis (porosity and osteophytes) is more strongly liked with age than osteoarthritis as defined by eburnation; therefore it is not appropriate to combine the results for OA and possible OA for this skeletal sample, as doing so could obscure any variation in prevalence due to social status, rather than age.

ii) Osteoarthritis and Status

In order to identify differences in the patterns of joint disease that might be associated with physical stress between the artefact groups, the joint surfaces were pooled together as functional joints, and osteoarthritis (OA) and possible osteoarthritis (?OA) were recorded as being present if one or more of the articular surfaces was affected. Each functional joint therefore represents the joint from one individual.

Tables showing the number (in brackets) and the percentage of joints from the left and right sides of the upper and lower limbs that were affected by osteoarthritis and possible osteoarthritis, and the percentage and number of individuals affected from each of the burial artefact groups in the skeletal sample from Castledyke South are presented in Appendix 2.1 Group 2 had the highest number and percentage of individuals with OA and ?OA in one or more of the joints from the upper limb, closely followed by Group 3.

Figure 4.3.1a shows the percentage of joints from the left and right upper limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Castledyke South. From this figure is it apparent that there were differences in the joints that were most frequently affected with osteoarthritis between the artefact groups. Group 3 individuals had the highest percentage of joints affected (right elbow and right wrist) and Group 4 individuals had no joints with OA from the right side of the upper limb. The difference in the number of right elbow joints affected between the artefact groups was significant (chi squared p= 0.01, $\alpha = 0.05$).

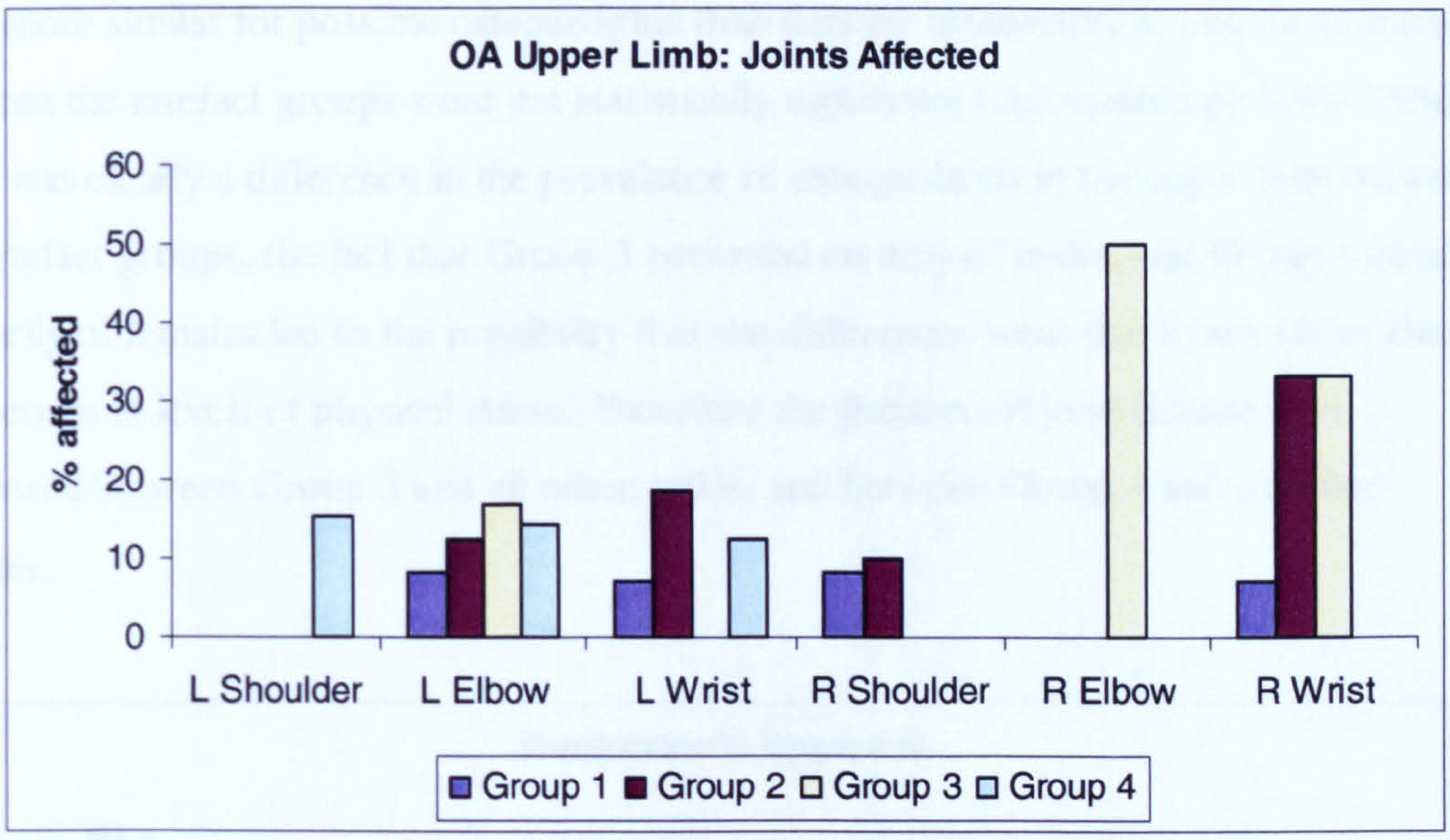


Figure 4.3.1a: The percentage of joints in each artefact group that were affected by osteoarthritis in both males and females from Castledyke South. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.3.1b shows the percentage of joints from the left and right sides of the upper limb that were affected by possible osteoarthritis.

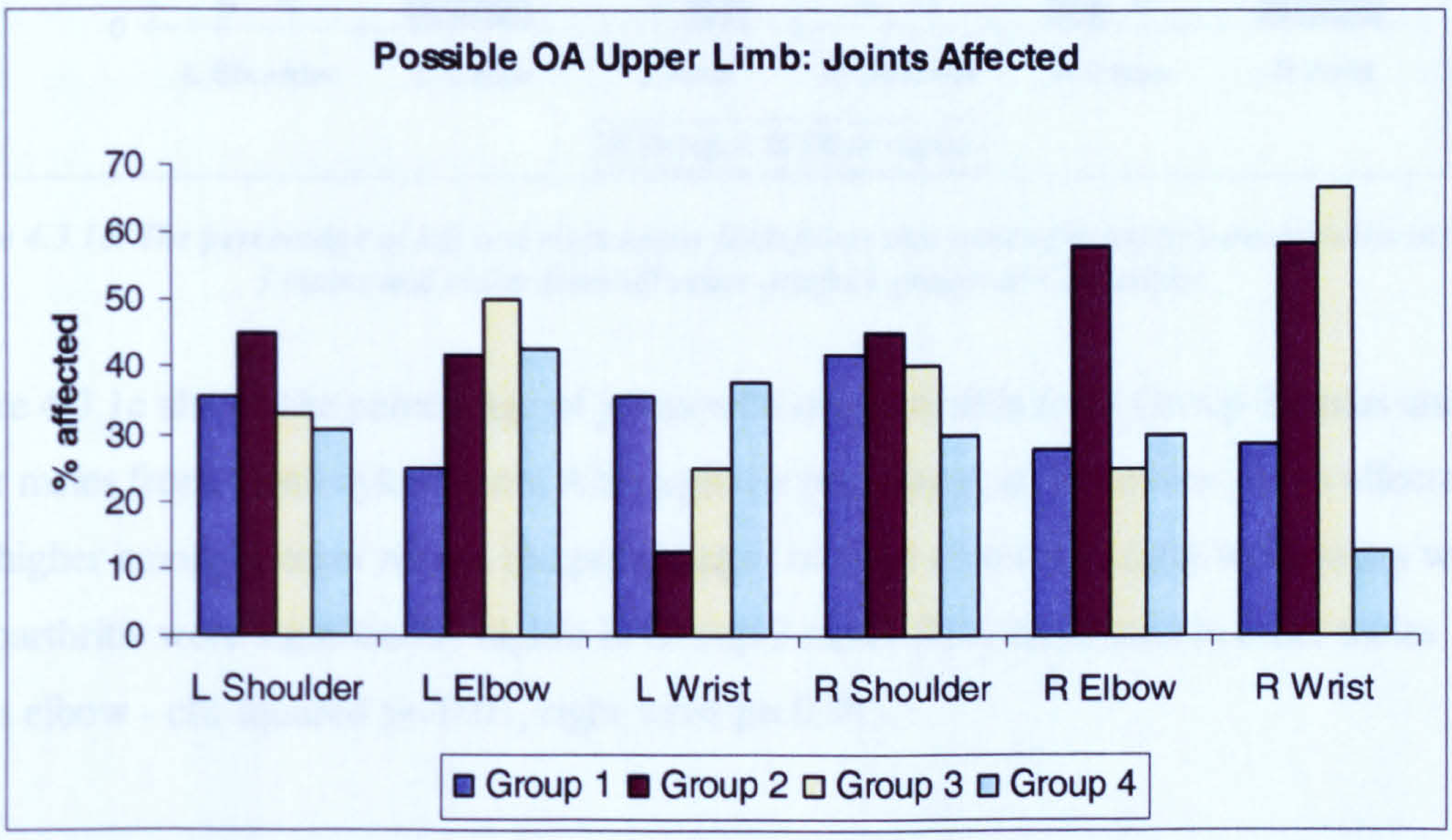


Figure 4.3.1b: The percentage of joints in each artefact group that were affected by possible osteoarthritis in both males and females from Castledyke South. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

As with osteoarthritis, individuals from Group 3 (weapon burials) had the highest percentage of joints affected, in the right wrist, but overall the patterns of joint involvement were more similar for possible osteoarthritis than definite osteoarthritis, and the differences between the artefact groups were not statistically significant (chi squared p= 0.4). Although there was clearly a difference in the prevalence of osteoarthritis in the upper limb between the artefact groups, the fact that Group 3 consisted entirely of males, and Group 4 consisted primarily of females led to the possibility that the differences were due to sex rather than differences in levels of physical stress. Therefore the patterns of joint disease were compared between Group 3 and all other males, and between Group 4 and all other females.

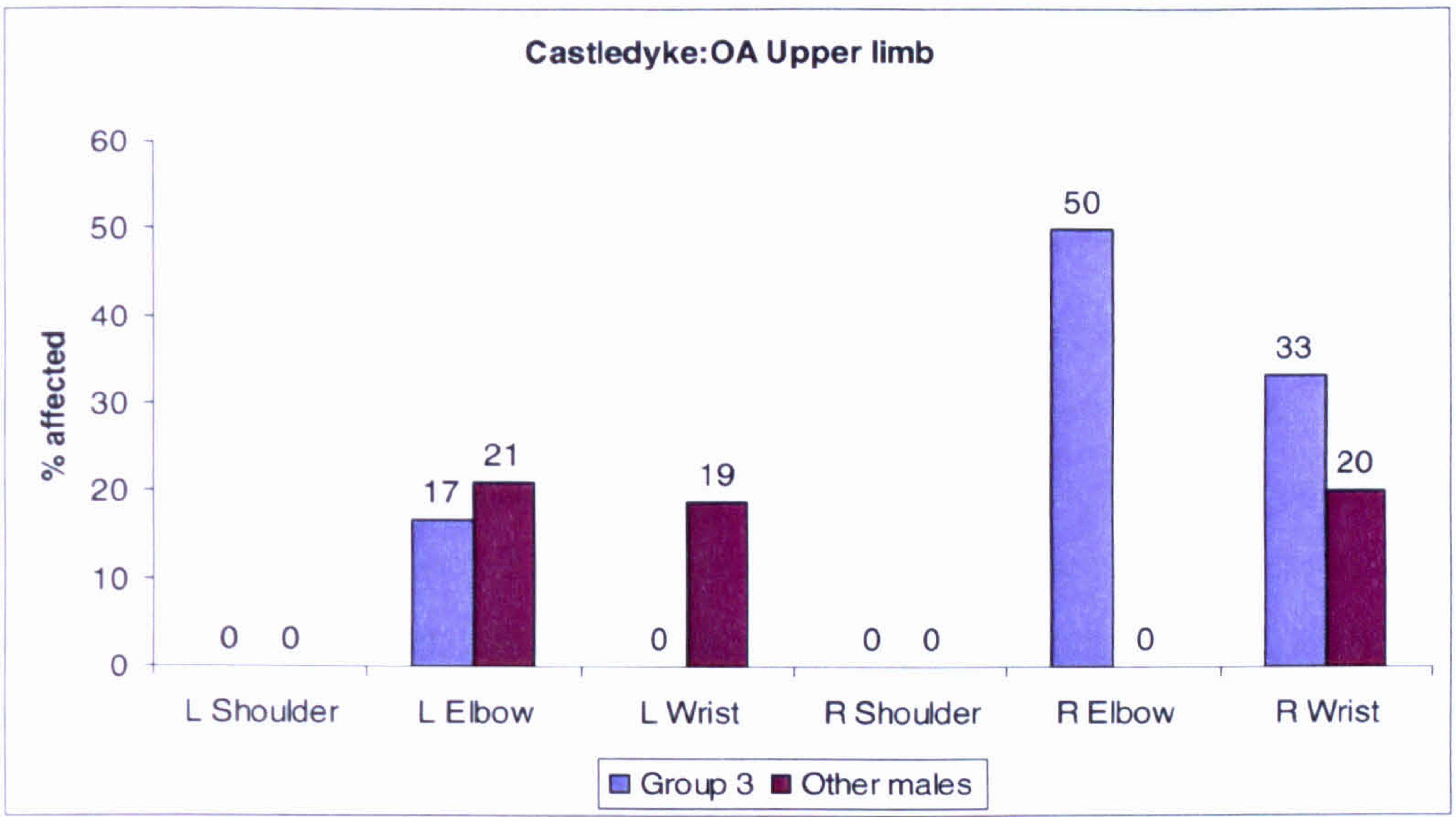


Figure 4.3.1c: The percentage of left and right upper limb joints that were affected by osteoarthritis in Group 3 males and males from all other artefact groups at Castledyke

Figure 4.3.1c shows the percentage of joints with osteoarthritis from Group 3 males and all other males from Castledyke South. Although the percentage of left elbow joints affected was higher amongst other males, the percentages of right elbow and right wrist joints with osteoarthritis were significantly higher in Group 3 males than those seen in other males (right elbow - chi squared p= 0.01, right wrist p= 0.01).

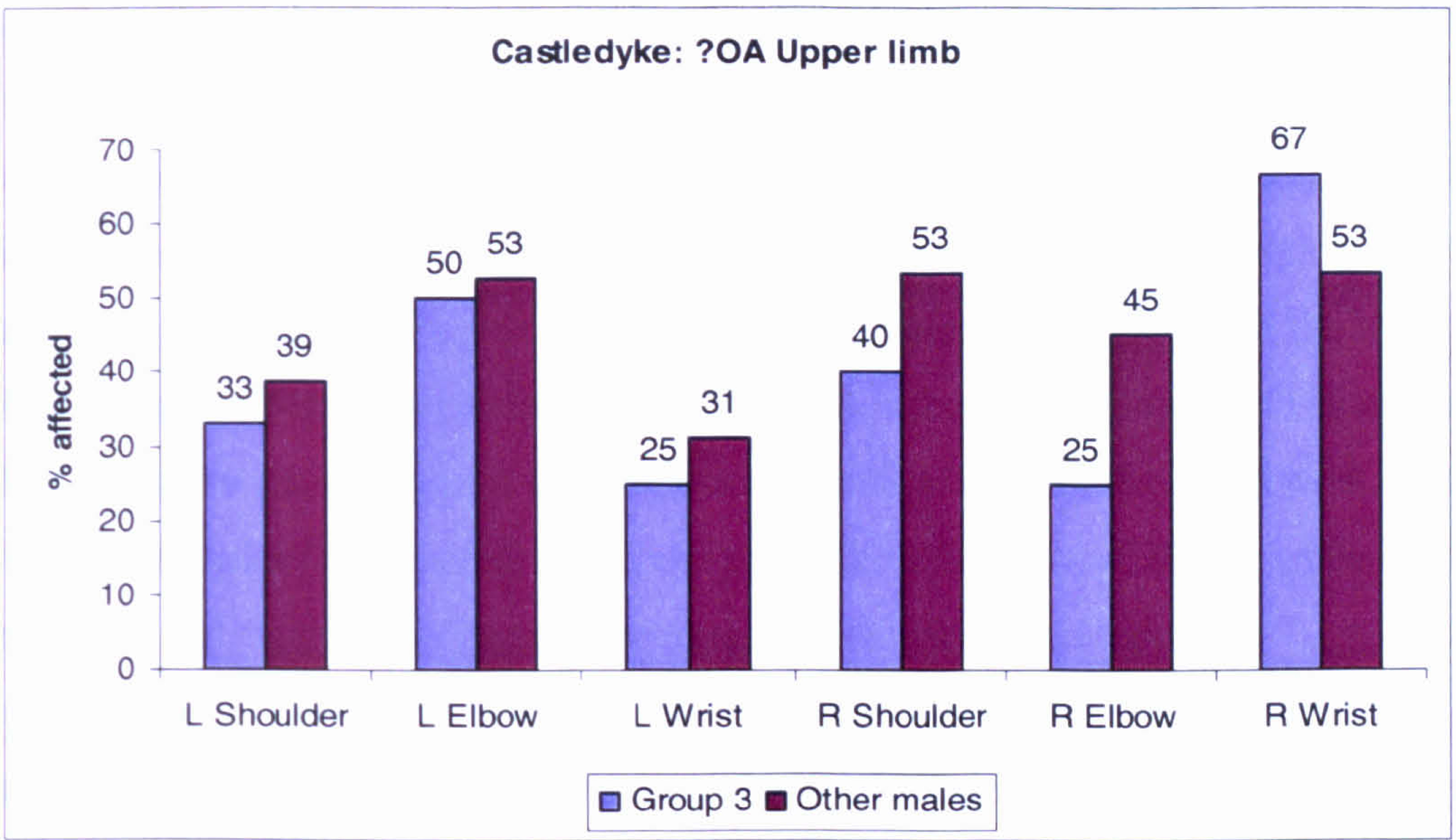


Figure 4.3.1d: The percentage of left and right upper limb joints in that were affected by possible osteoarthritis in Group 3 males and males from all other artefact groups at Castledyke

Figure 4.3.1d shows the percentage of joints from Group 3 and all other males that had possible osteoarthritis. This figure shows that the percentage of left wrist joints that were affected by changes was smaller in Group 3 than in all other males, while the percentage of right wrists was higher in Group 3. The percentage of left wrist joints that were affected in Group 3 was significantly lower than those from all other males (chi squared p=0.01), while the percentage of right wrists that were affected was significantly higher in Group 3 than in all other males (chi squared p=0.02).

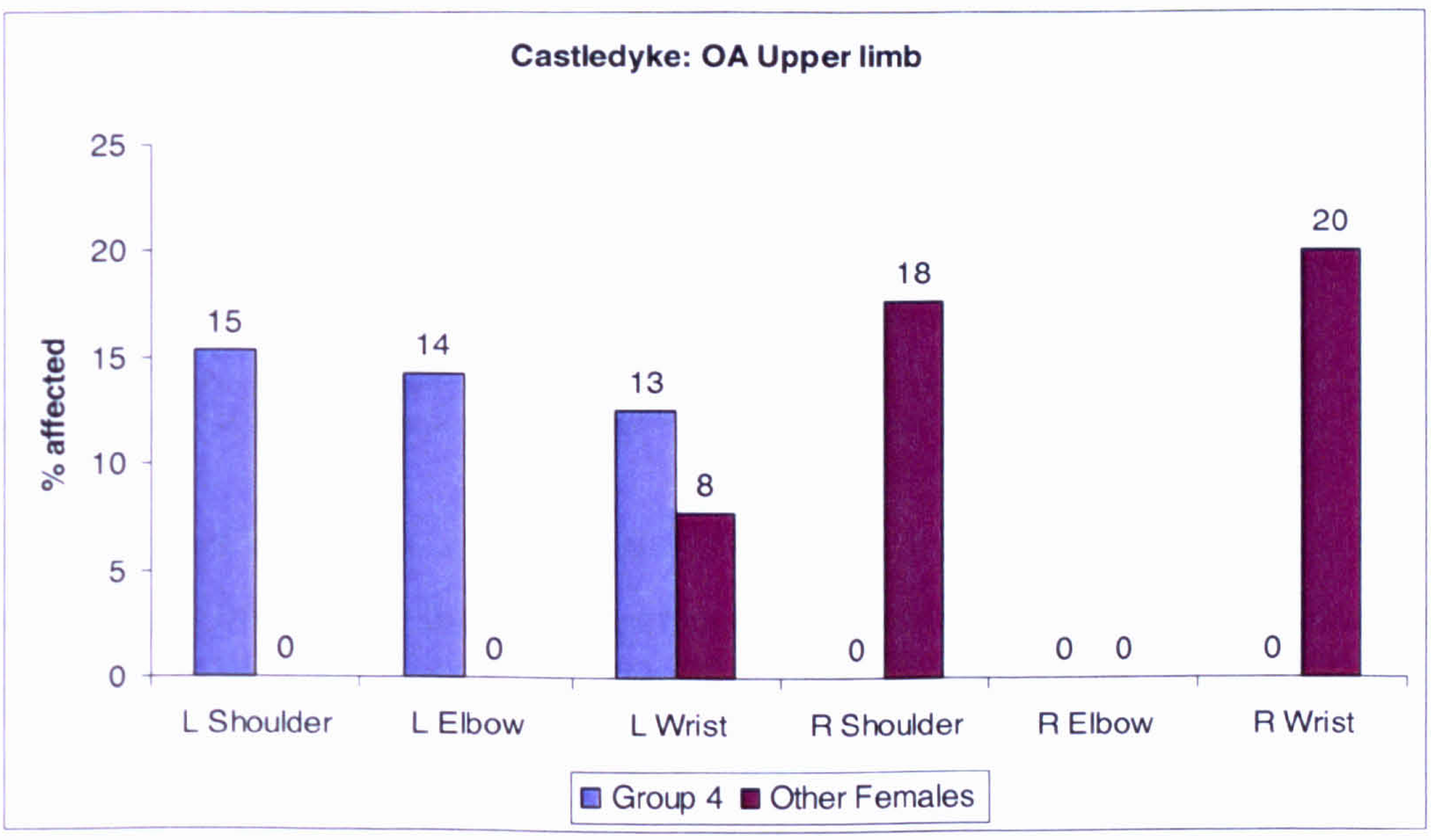


Figure 4.3.1e: The percentage of left and right upper limb joints in each artefact group that were affected by osteoarthritis in Group 4 and females from all other artefact groups at Castledyke

Figure 4.3.1e shows the percentage of joints from both sides of the upper limb of Group 4 individuals and all other females that were affected by osteoarthritis, while Figure 4.3.1f shows the percentage of joints with possible osteoarthritis in these two groups. The most striking differences are that there were no joints with osteoarthritis from the right side from Group 4 females, although possible osteoarthritis was present in all joints, and the left shoulder and elbow were not affected by OA in all other females. Group 4 individuals had significantly higher percentages of possible osteoarthritis in the left elbow and wrist joints than all other females (chi squared; left elbow p= 0.006, left wrist p=0.0006), while all other females had significantly higher percentages of individuals with possible enthesopathy in the right elbow (p= 0.05) and right wrist (p=0.002). These differences suggest that there may have been variations in the type and degree of stress to which the right and left sides of the upper limbs were exposed between the artefact groups at Castledyke.

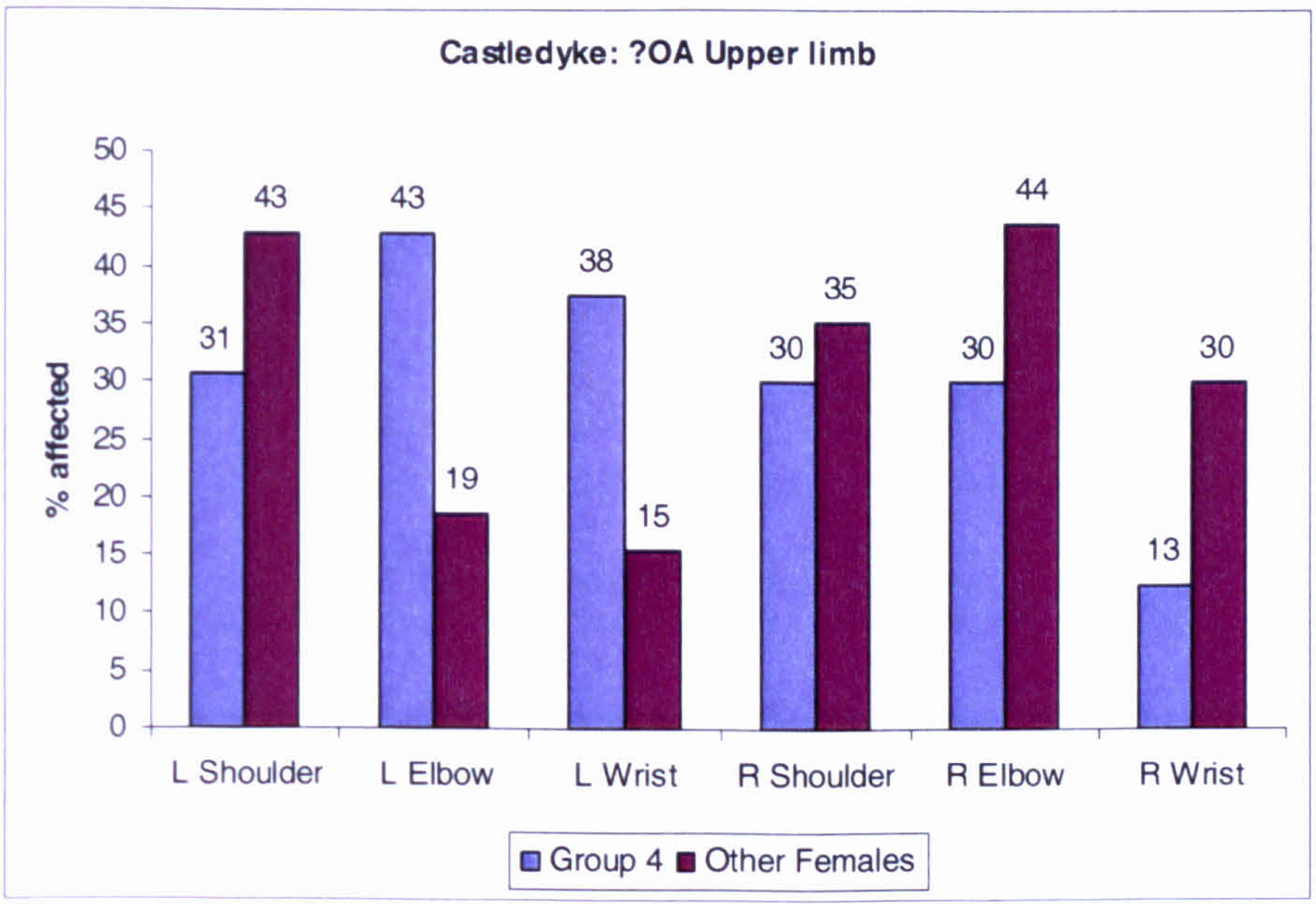


Figure 4.3.1f: The percentage of left and right upper limb joints in each artefact group that were affected by osteoarthritis and possible osteoarthritis in Group 4 and females from all other artefact groups at Castledyke

The percentage of individuals affected with osteoarthritis was similar to that seen in the upper limb, but Group 3 had the highest percentage of individuals affected by osteoarthritis and possible osteoarthritis in the lower limb. Figure 4.3.1g shows the percentage of joints from the left and right lower limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Castledyke South. As with the upper limb, there were differences between the artefact groups in the location and percentage of joints that were affected; Group 3 had a high frequency of individuals with knee and left ankle joints affected, and Groups 2 and 4 had low frequencies of changes in all joints. The difference in the percentage of left knee joints affected from Group 3 was significantly higher than the other three artefact groups (chi squared p=0.001), as was the percentage of left ankle joints (p=0.2). Figure 4.3.1h shows the percentage of lower limb joints with possible osteoarthritis in each of the artefact groups, and again like the upper limb joints the differences between the artefact groups were less distinct than when definite osteoarthritis is considered. Group 1 had much lower levels of possible osteoarthritis in both ankle joints, and there was little possible osteoarthritis in the left ankle from Group 4 individuals.

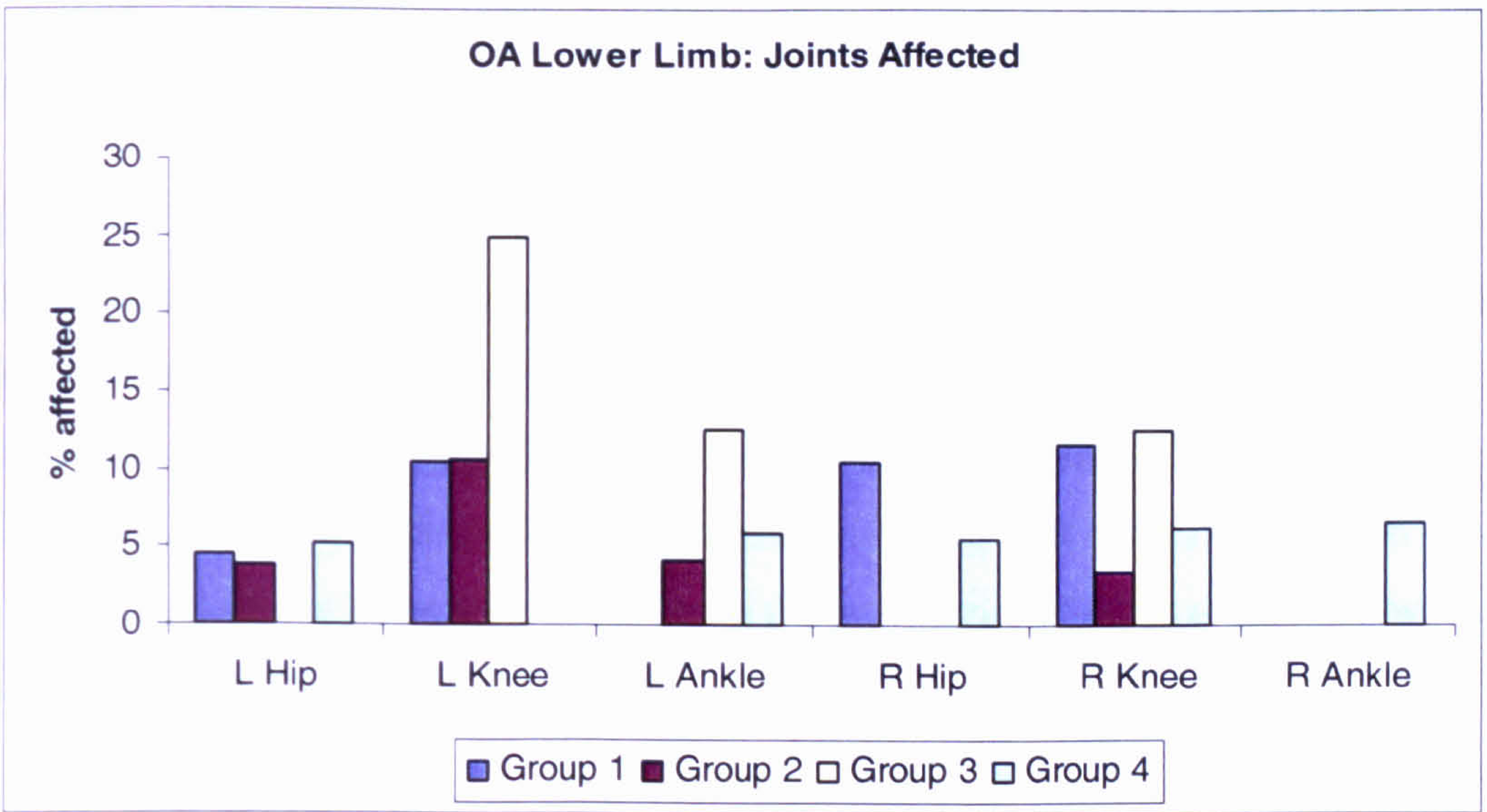


Figure 4.3.1.g: The percentage of upper limb joints with osteoarthritis from each artefact group at Castledyke. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

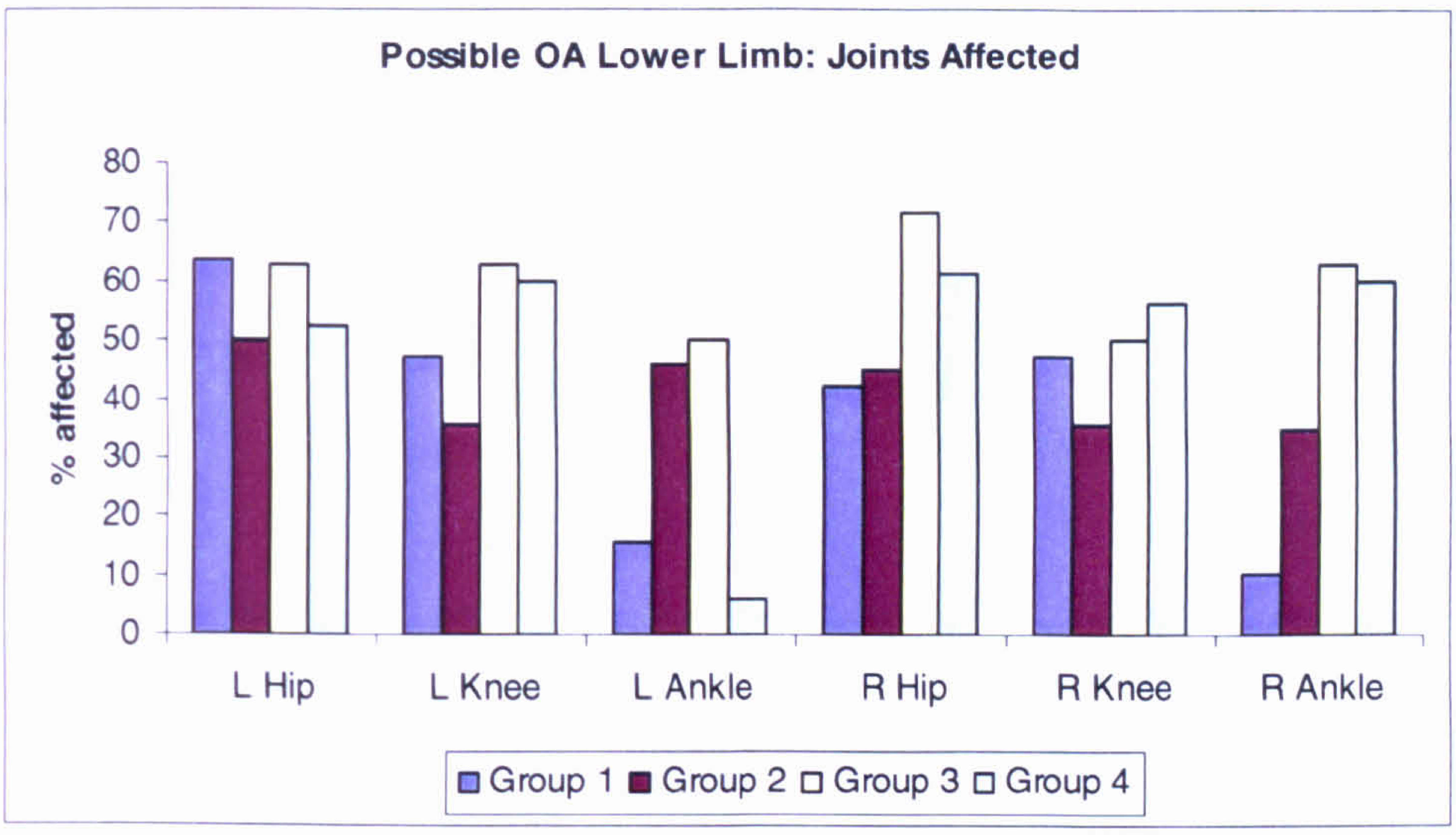


Figure 4.3.1h: The percentage of upper limb joints with osteoarthritis from each artefact group at Castledyke. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

In order to explore the possibility that the differences identified between the artefact groups were due to sex rather than other factors such as differences in activity levels, the results from Group 3 were compared with other males, while the results from Group 4 were compared with other females. Figure 4.3.1i shows the percentage of joints from the lower limb with osteoarthritis from Group 3 males and all other males from Castledyke. From this figure it is clear that there are differences in the percentage of joints affected between Group 3 males and other males.

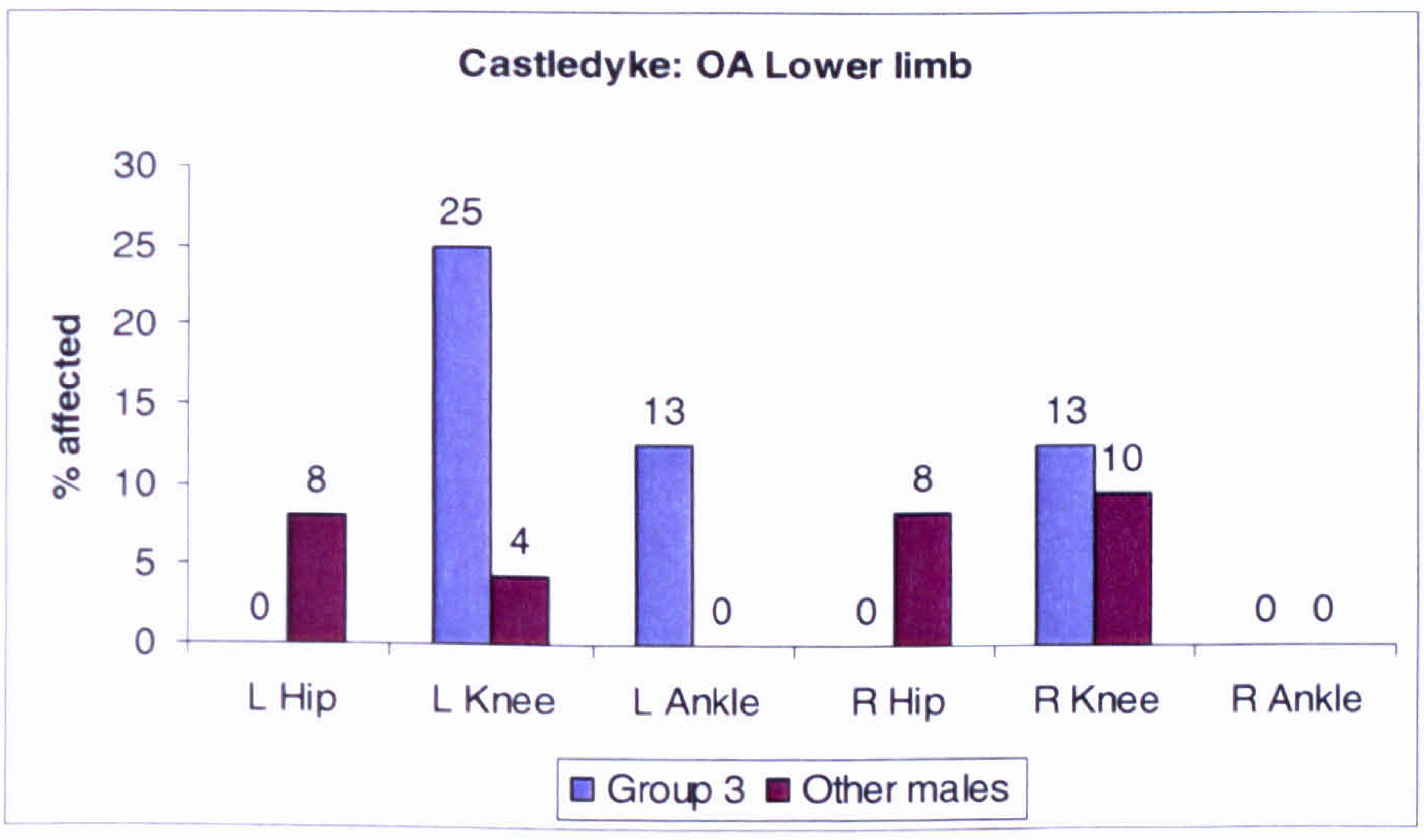


Figure 4.3.1i: The percentage of left and right lower limb joints that were affected by osteoarthritis in Group 3 males and males from all other artefact groups at Castledyke

Figure 4.3.1j shows the percentage of lower limb joints from Group 3 individuals and all other males that were affected by possible osteoarthritis. In all joints where ?OA was seen in Group 3, Group 3 males had a higher percentage of joints affected than all other males.

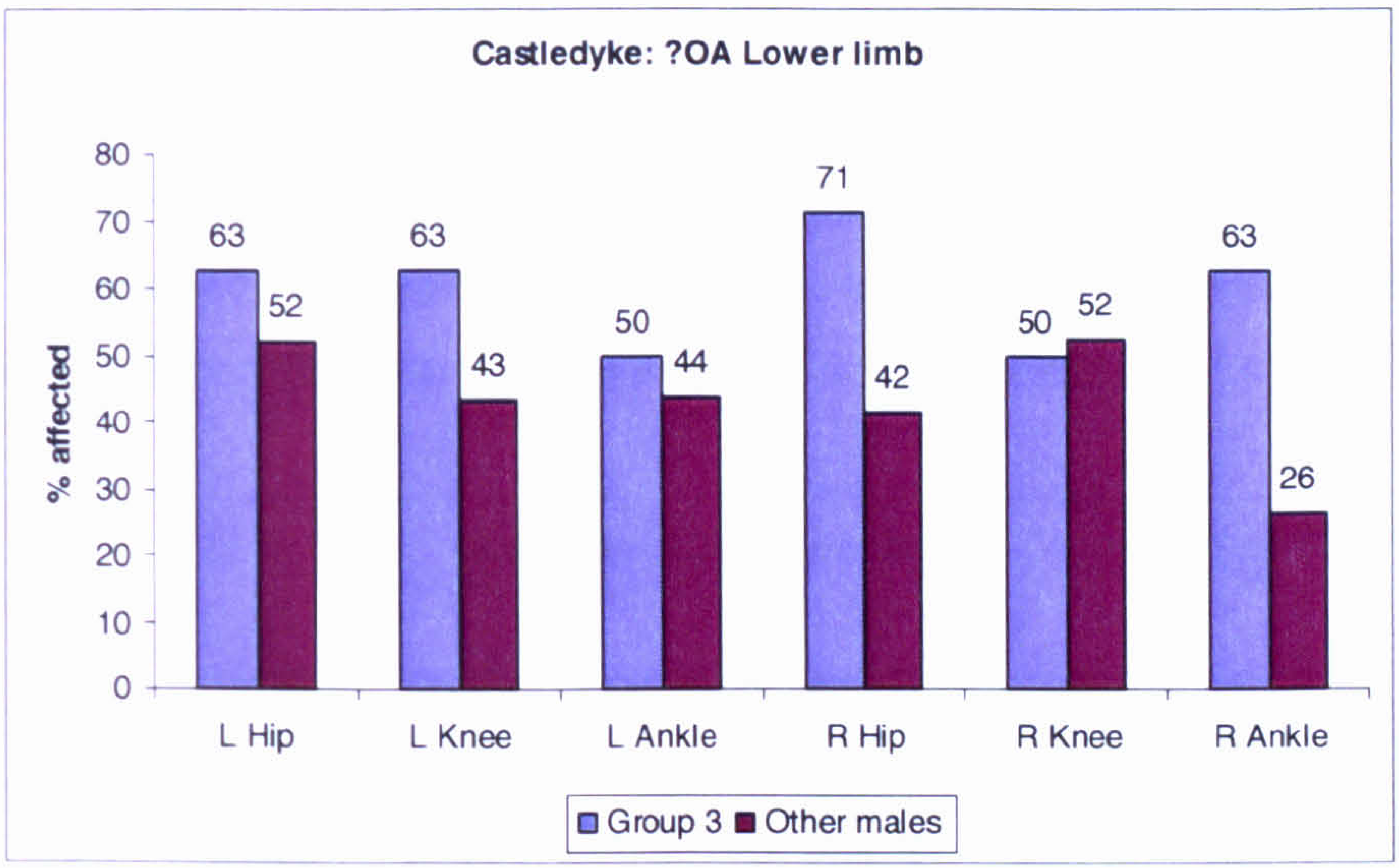


Figure 4.3.1j: The percentage of left and right lower limb joints that were affected by possible osteoarthritis in Group 3 males and males from all other artefact groups.

Figure 4.3.1k shows the percentage of joints from the lower limb from Group 4 individuals and all other females that were affected by osteoarthritis, while Figure 4.3.1l shows the percentage of joints from these two groups that were affected by possible osteoarthritis.

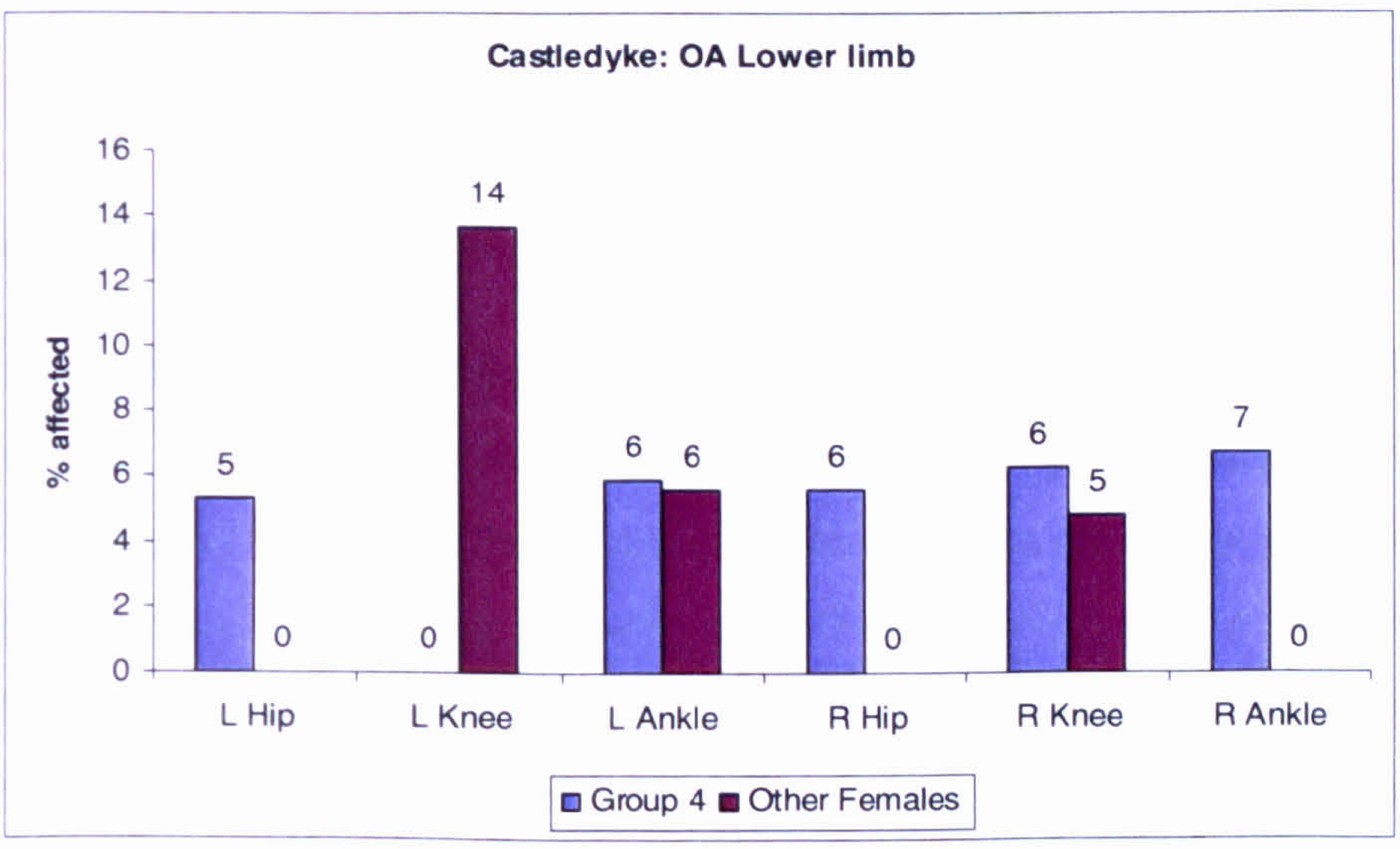


Figure 4.3.1k: The percentage of left and right lower limb joints that were affected by osteoarthritis in Group 4 and females from all other artefact groups.

Group 4 had a similar prevalence of osteoarthritis to all other females in the left ankle and right knee, but in the hips and right ankle only Group 4 individuals were affected. When possible osteoarthritis was compared between the two groups, Group 4 had a higher percentage of joints from the right side affected than all other females, but the percentage of left ankle joints affected in Group 4 was significantly smaller than the percentage for all other females affected (chi squared p= 0.0001), while the percentage of right ankle joints affected in Group 4 was significantly higher than that seen from all other females (p=0.001). These results suggest that there may have been a factor influencing the pattern of joint disease between Group 4 individuals and all other females.

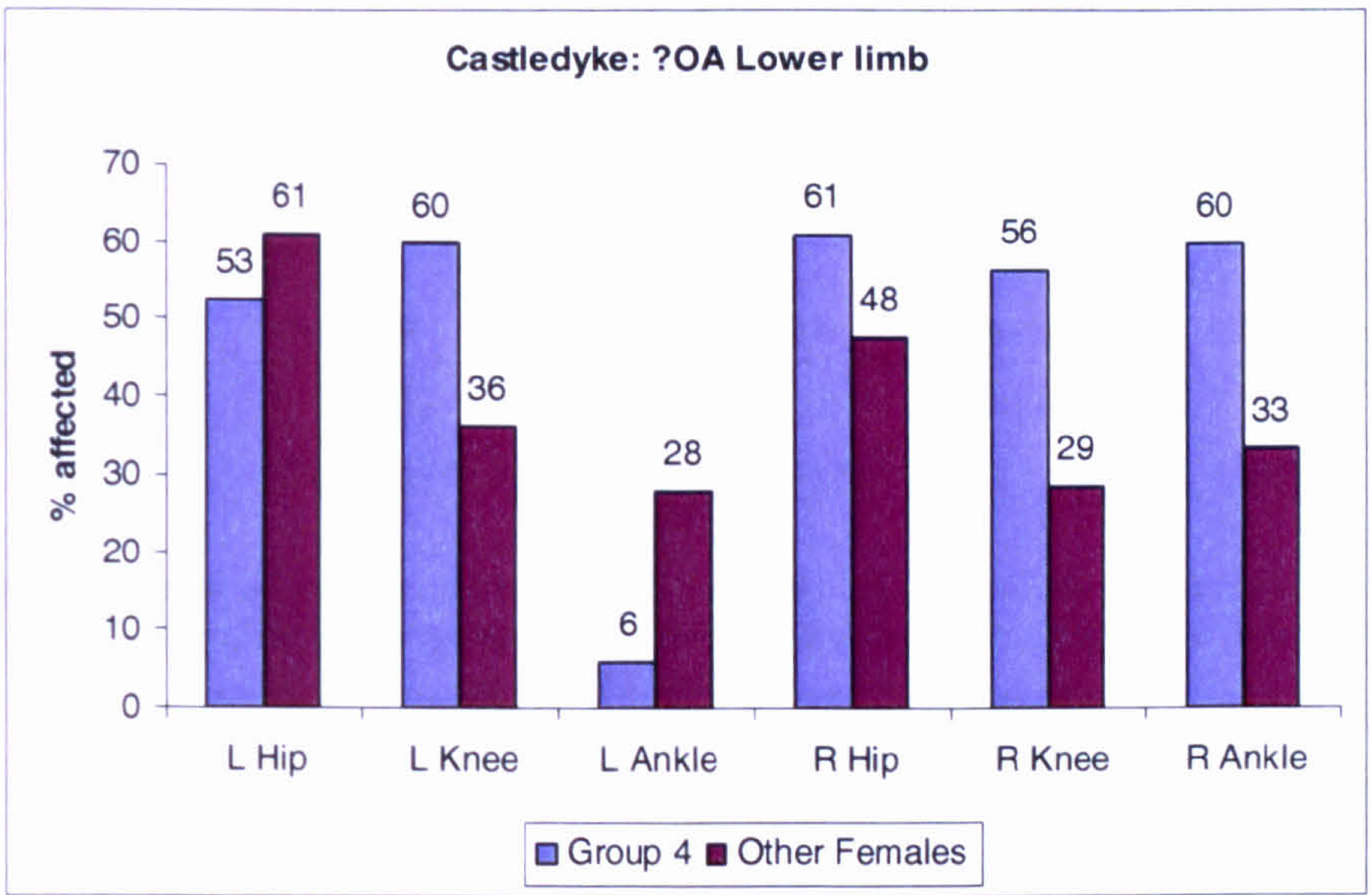


Figure 4.3.11: The percentage of left and right lower limb joints that were affected by possible osteoarthritis in Group 4 females and females from all other artefact groups.

4.3.2 Norton Mill Lane

From the total sample of 51 individuals examined from Norton Mill Lane, 50 individuals had joint surfaces preserved, of which 11 individuals (22%) had porosity and osteophytes, and nine individuals (18% of the total sample) had eburnation in one or more joints. Tables showing the number and percentage of each joint surface observed, and the number and percent affected by porosity and osteophytes (?OA), porosity, osteophytes and eburnation (OA) on the left and right sides of the upper and lower limbs are presented in Appendix 2.2. The distal radius had the lowest frequency of changes, from both sides of the upper limb; the highest frequency of possible OA was seen in the distal ulna, and the highest frequency of osteoarthritis was seen in the right distal humerus, but generally in the upper limb, few joints were affected by joint disease. Eburnation was only seen in the glenoid fossa, right distal humerus and left proximal radius. In the lower limb, the acetabulum showed the most changes, with both sides being affected by OA and ?OA. In both the acetabulum and femoral head, the percentage of joints with ?OA was greatest on the right side, while the percentage of joints showing eburnation was greatest on the left side. Overall, the percentage of joint surfaces with osteoarthritis and possible osteoarthritis was much lower than that seen at Castledyke South.

Table 4.3.2a shows the number of individuals present for observation from each sex and the average number of functional joints present in the upper and lower limbs, and the average number affected by osteoarthritis and possible osteoarthritis. The number of joints from each sex is given in brackets.

	No. of	Upper Limb			Lower Limb		
Sex	SK	Present	OA	?OA	Present	OA	?OA
Female	19	4.1 (65)	0.1 (1)	0.3 (5)	4.8 (91)	0.2 (4)	0.3 (6)
Male	27	3.4 (84)	0.1 (3)	0.4 (10)	4.4 (119)	0.1 (4)	0.2 (6)

Table 4.3.2a: The number of females and males with joints present and the average number of joints present, with OA and with possible OA in the upper and lower limbs. The number of joints present is given in brackets.

In the upper limb, the average number of joints with osteoarthritis was the same in females and males, and the number of joints with possible osteoarthritis was slightly higher on average in males than in females. However in the lower limb, the average number of joints with osteoarthritis and possible osteoarthritis was higher in females than in males.

i) Osteoarthritis, Age and Sex

Table 4.3.2b shows the number and percentage of joints from both sides of the upper and lower limbs affected with osteoarthritis (OA, where eburnation was observed in the joint), possible osteoarthritis (?OA, where porosity and osteophytes were observed), and the percentage that were not affected (None) in females and males from each of the age groups in the Norton Mill Lane skeletal sample. Amongst the females, the percentage of joints with osteoarthritis was highest in the Older and Adult age groups, and the greatest percentage of possible osteoarthritis was in the Middle age group. In males, the percentage of osteoarthritis was lowest in the Young and Young/Middle age groups, and highest in the

Middle aged and Adult age groups. Possible osteoarthritis was highest in the Middle aged and Adult age groups.

Age Group	Female OA	Female ?OA	Female None	Male OA	Male ?OA	Male None
Young	0.5 (1)	0 (0)	51 (106)	0 (0)	0 (0)	40 (83)
Young/ Middle	0 (0)	2 (4)	57 (103)	1 (2)	2 (4)	48 (87)
Middle	0 (0)	9 (8)	47 (42)	2 (4)	4 (9)	36 (87)
Older	7 (4)	0 (0)	32 (19)	1 (2)	2 (3)	25 (38)
Adult	10 (3)	0 (0)	3 (1)	2 (1)	3 (2)	25 (15)

Table 4.3.2b: The percentage of joints from both sides of the upper and lower limbs, in each age group affected by OA, possible OA and not affected from females and males. The number of joints in each age group is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

When the results were examined using a Chi Squared test corrected for small sample size using Yates' correction for continuity, the variation in the pattern of osteoarthritis and possible osteoarthritis between the age groups in females was statistically significant with p values of less than 0.01, but in males only the variation in possible osteoarthritis was statistically significant with a p value of 0.05. In both sexes, possible OA was correlated with age, but the relationship between OA and age was more complex.

i) Osteoarthritis and Status

Tables showing the number (in brackets) and the percentage of joints from the left and right sides of the upper and lower limbs that were affected by osteoarthritis and possible osteoarthritis, and the percentage and number of individuals affected from each of the burial artefact groups in the skeletal sample from Mill Lane are presented in Appendix 2.2.

The percentage of individuals with OA and ?OA was highest in Group 3, and none of the Group 4 or Group 1 individuals were affected in the upper limb. Figure 4.3.2a shows the percentage of joints from the left and right upper limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Norton Mill Lane. Only individuals from Groups 2 and 3 were affected by osteoarthritis in the joints from the upper limb, and Group 3 individuals had the highest percentage of left shoulder and right elbow joints affected.

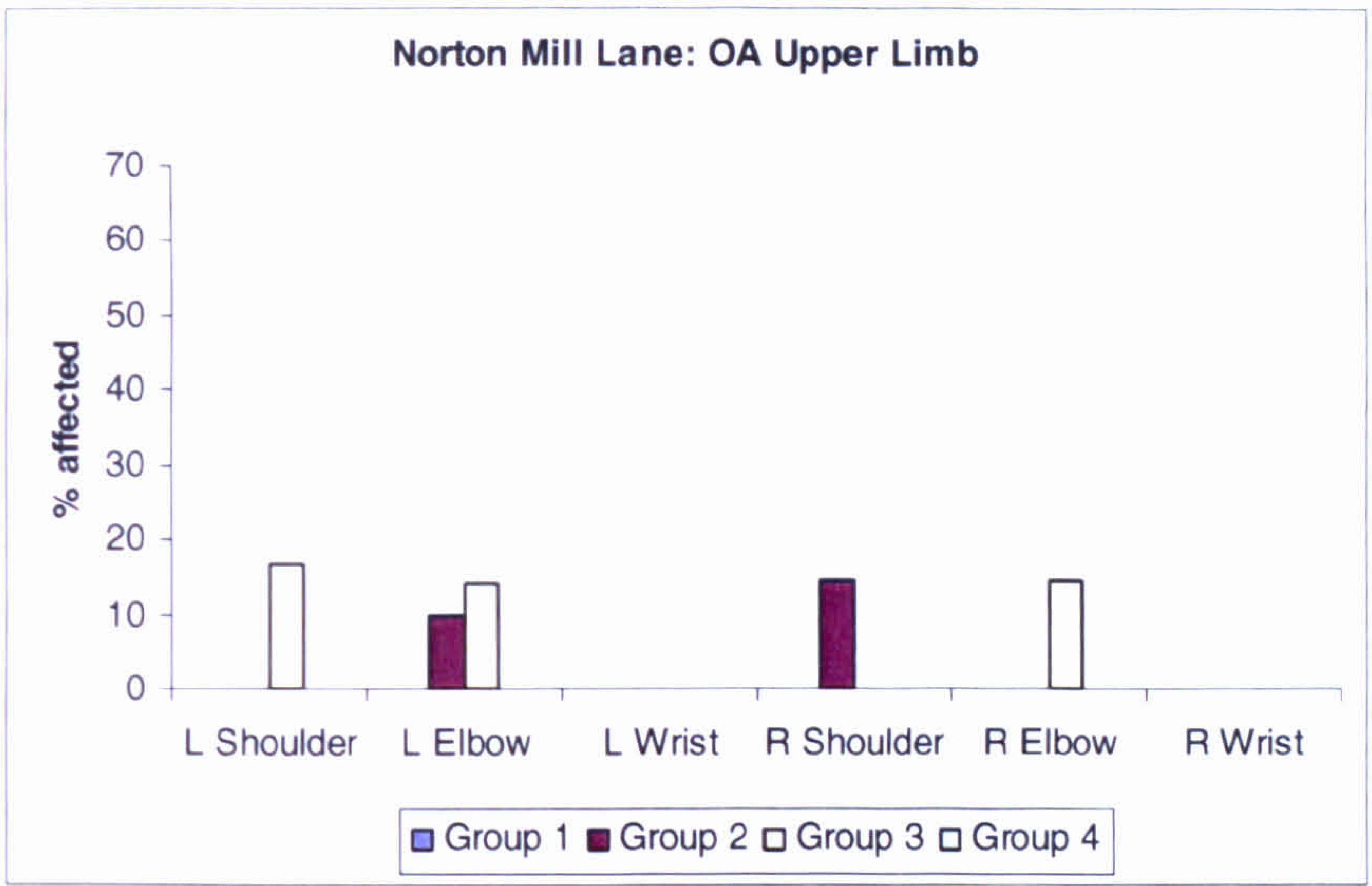


Figure 4.3.2a: The percentage of joints in each artefact group that were affected by osteoarthritis in both males and females from Norton Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.3.1b shows the percentage of joints from the left and right sides of the upper limb that were affected by possible osteoarthritis; as with osteoarthritis, only Groups 2 and 3 were affected, and the percentage of wrist and right elbow joints with possible osteoarthritis was higher in Group 3 than in Group 2, although the percentage of shoulder and left elbow joints involved was higher in Group 2.

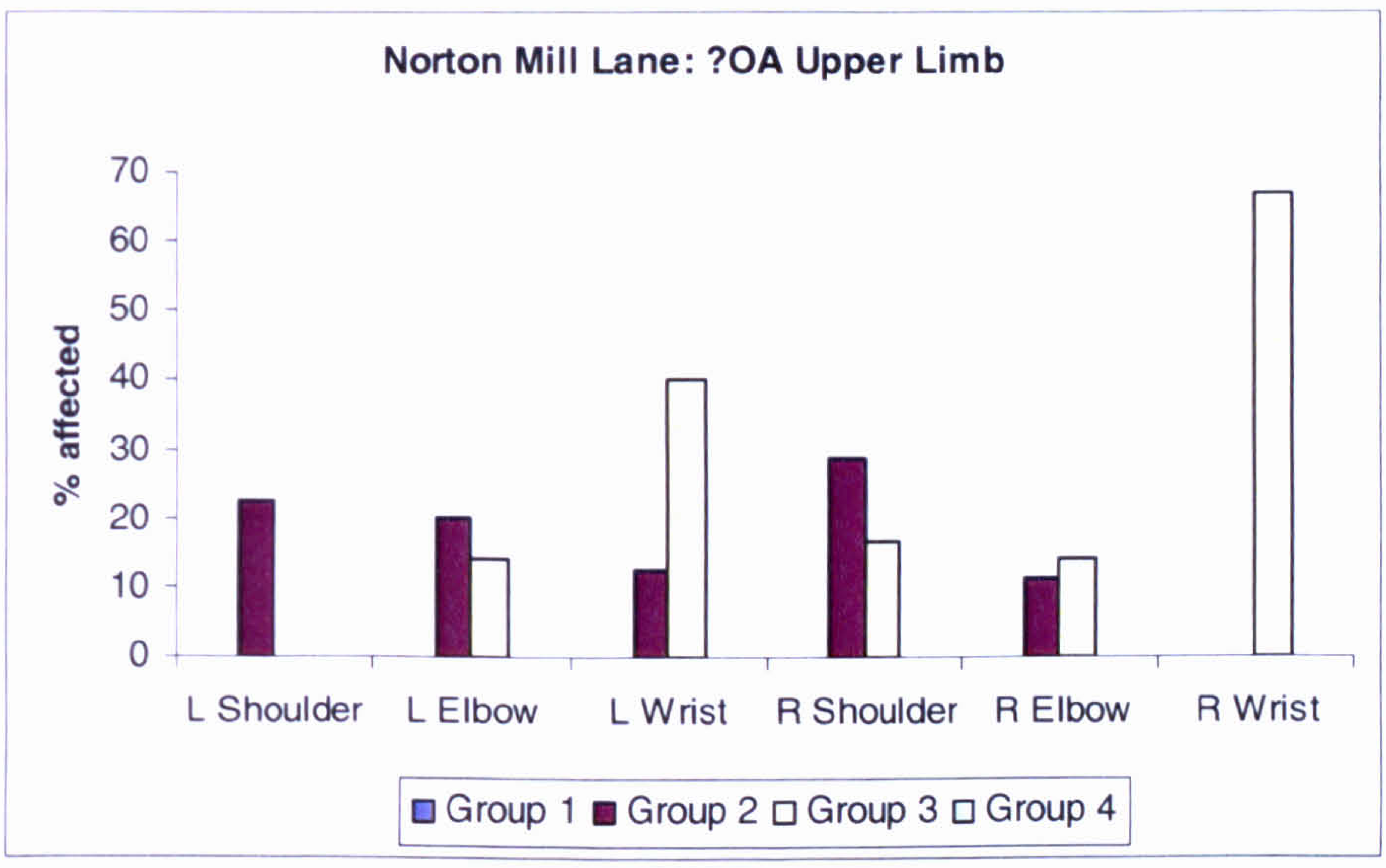


Figure 4.3.2b: The percentage of joints in each artefact group that were affected by possible osteoarthritis in both males and females from Norton Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

As the numbers of joints with osteoarthritis and possible osteoarthritis from Norton Mill Lane were very small, the data were pooled to examine the differences between Group 3 and all other males. Pooling the data did not obscure the differences seen between Group 3 individuals and the other groups. As there were no individuals affected from Group 4 there was no need to compare this group with other individuals.

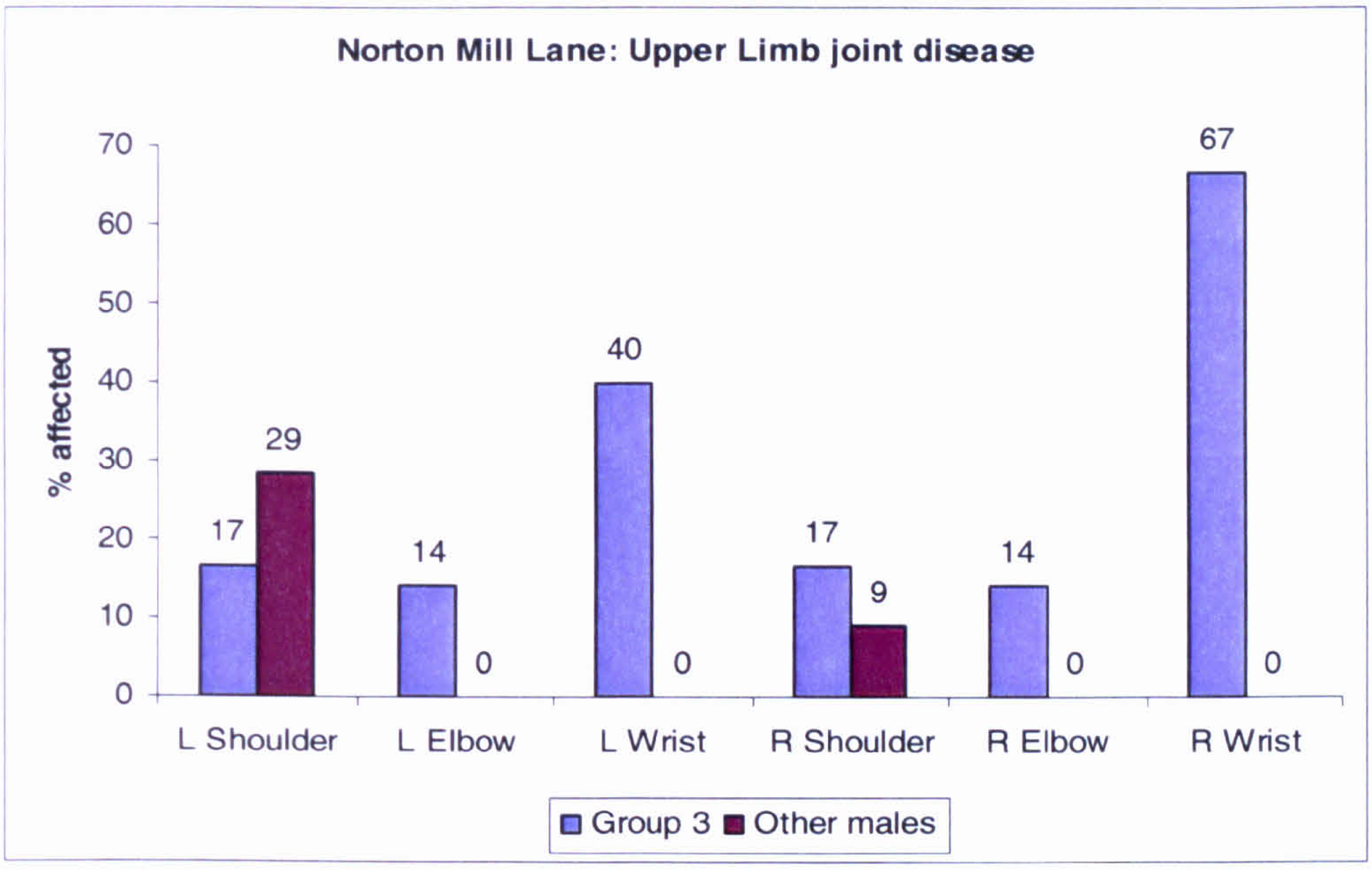


Figure 4.3.2c: The percentage of joints with OA or ?OA from Group 3 and all other males from Norton Mill Lane

Figure 4.3.2c shows the percentage of joints with osteoarthritis or possible osteoarthritis from Group 3 males and all other males from Norton Mill Lane. When the males from Group 3 were compared with all other males from Norton Mill Lane, other males were only affected in the shoulder joints, and the percentage of right shoulder joints affected was significantly higher in Group 3 (chi squared p=0.05). As the other joints were not affected in other males it was not possible to use a chi-squared test to determine the level of significance of the difference between the two groups. However, the results show that there was a distinct difference in the pattern of joints involved between Group 3 males, those buried with weapons, and all other males, particularly in the right side of the upper limb. Interestingly, the percentage of right wrist joints affected by changes was the same as that seen at Castledyke South, although the percentage of left wrists involved was much higher at Norton Mill Lane.

The number of individuals with joints affected by changes in the lower limb were very small, but Group 3 had the highest percentage of individuals with OA and ?OA in the joints of the lower limb. Figure 4.3.2d shows the percentage of joints from the left and right lower limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Norton Mill Lane. As with the upper limb, the highest percentages of joints affected were seen in Group 3, the males with weapons, but these individuals only had osteoarthritis in the left hip joints. Unlike the upper limb joints, individuals from Groups 1 and 4 also had joints from the lower limb that were affected by osteoarthritis, but none of the skeletons examined had osteoarthritis in the ankle joints and none of the Group 2 individuals had osteoarthritis in the lower limb. Individuals from Group 4 had the widest range of joints from the lower limb that were affected.

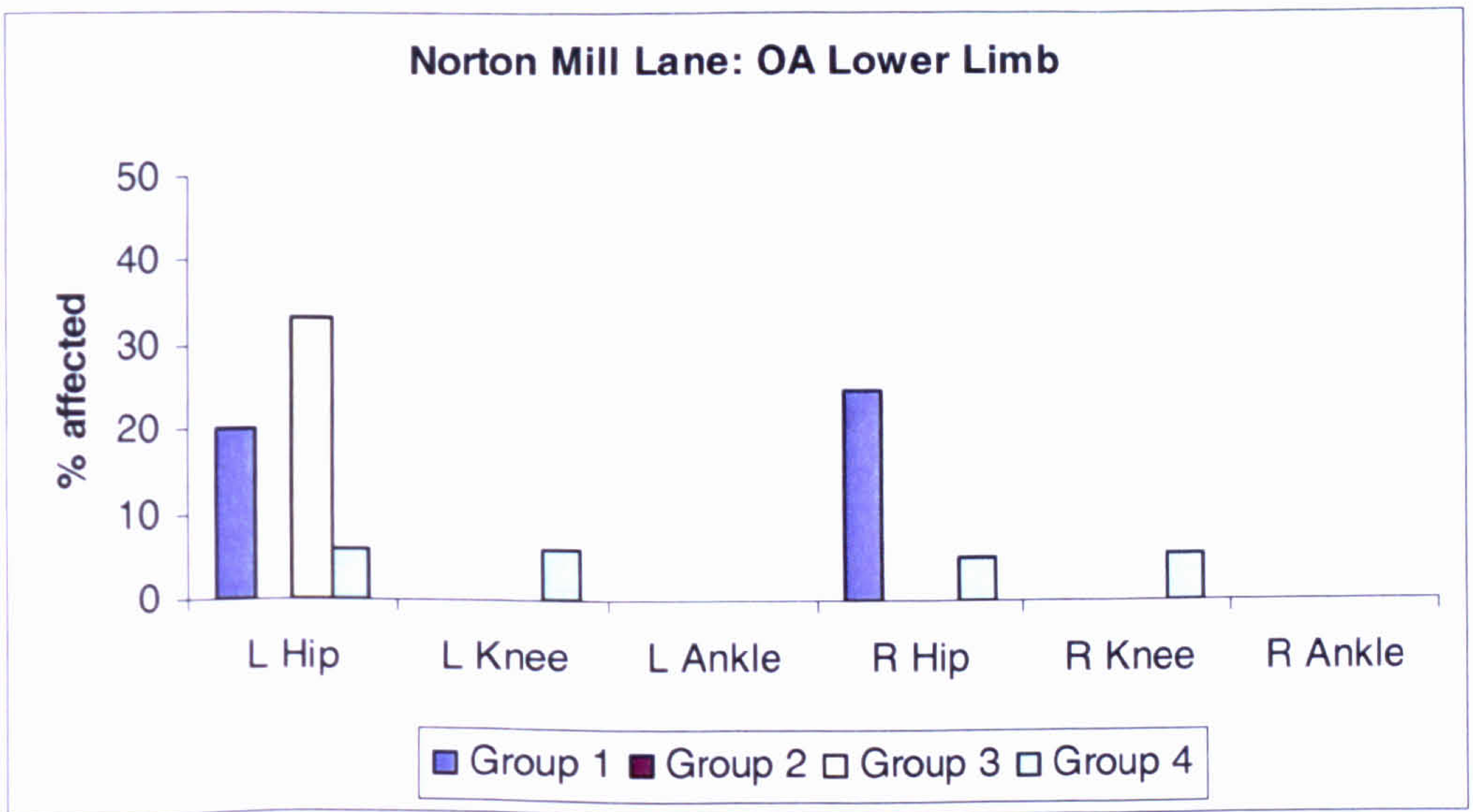


Figure 4.3.2d: The percentage of joints from the lower limb with osteoarthritis in each of the artefact groups from Norton Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.3.2e shows the percentage of joints from the lower limb with possible osteoarthritis from each of the artefact groups at Norton Mill Lane. Again, Group 3 had the highest percentage of joints affected, in the right hip, and none of the ankle joints were affected

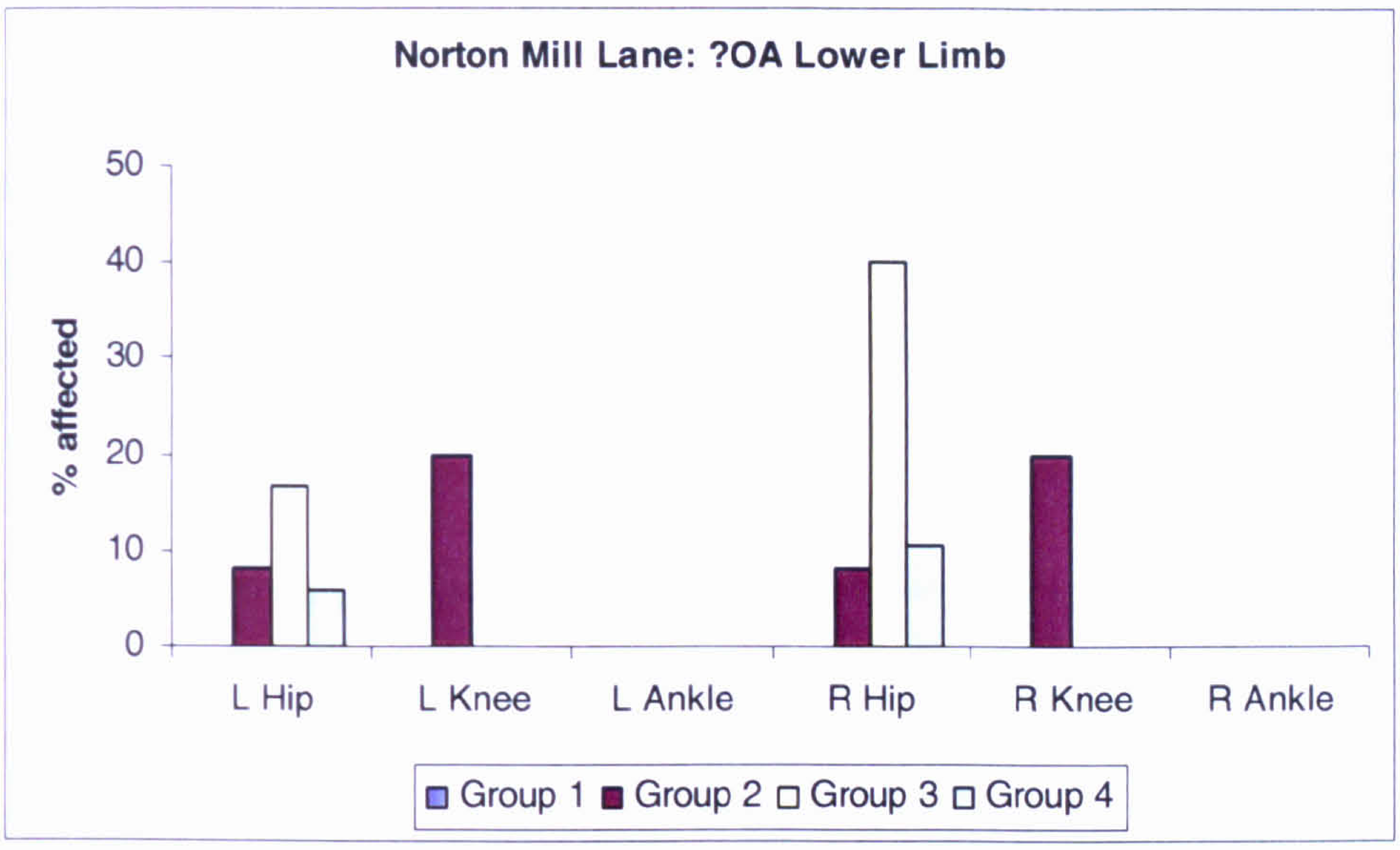


Figure 4.3.2e: The percentage of joints from the lower limb with possible osteoarthritis in each of the artefact groups from Norton Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

As the number of joints that were affected from the lower limbs was very small; as with the upper limb, the data were pooled to examine the differences between the artefact groups. Pooling the data did not obscure the differences in prevalence between the groups. Figure 4.3.2f shows the percentage of joints affected in Group 3 compared to all other males from Norton Mill Lane.

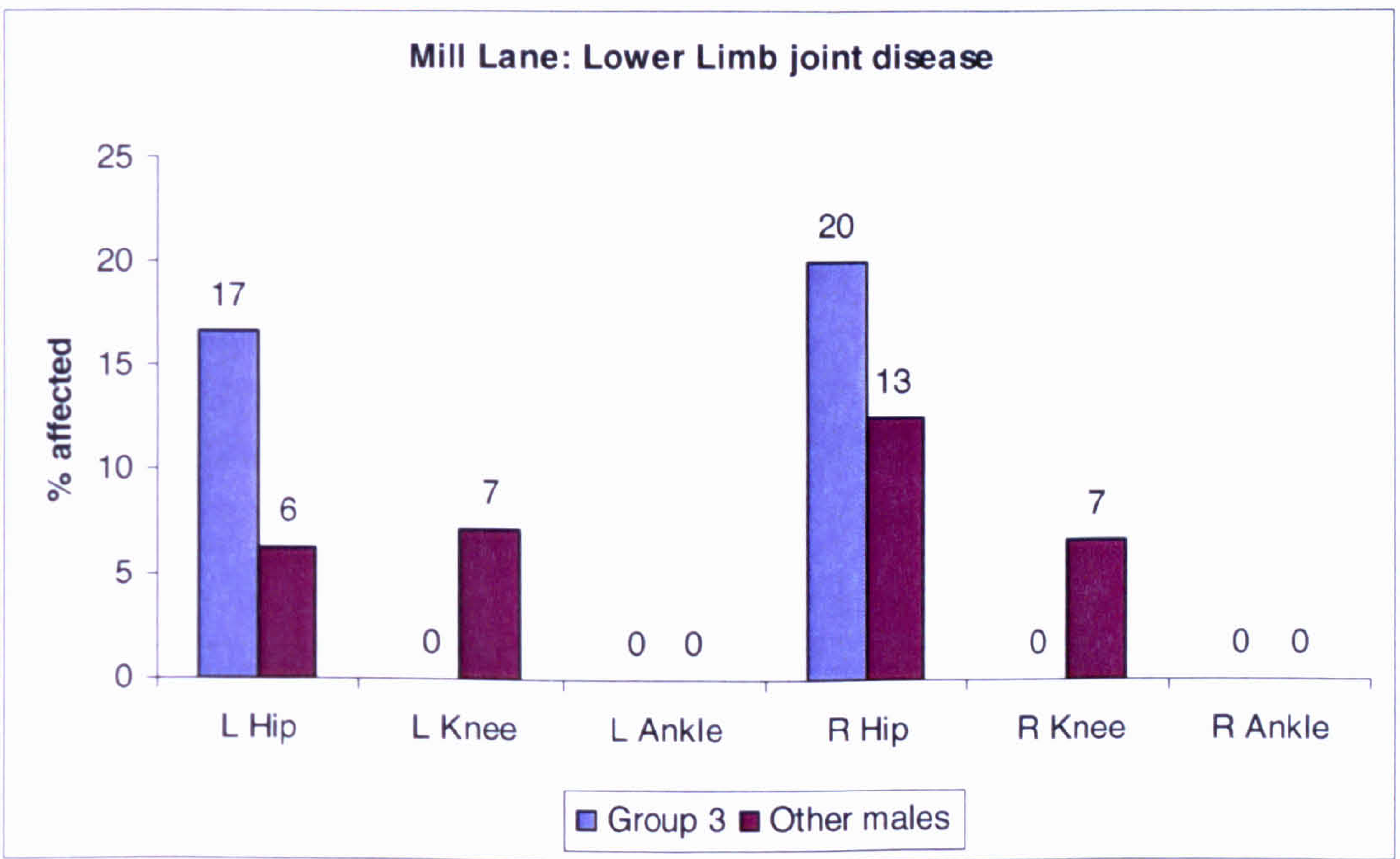


Figure 4.3.2f: The percentage of joints affected in the lower limb in Group 3 and all other males from Norton Mill Lane.

While the percentage of hip joints affected in Group 3 was higher in comparison with all other males, this difference was not significant (chi squared, left hip p= 0.5, right hip p= 0.6). The lack of involvement of the knee in Group 3 individuals compared with other males is striking, and suggests that there may have been a difference in the degree of physical stress to the knees between males buried with weapons and those without.

Figure 4.3.2g shows the percentage of joints from the lower limbs that were affected in Group 4 individuals and all others from Norton Mill Lane (as Group 4 included both females and males at Norton Mill Lane it is not realistic to compare this group with females alone). This figure shows that the percentage of joints affected in Group 4 was lower in comparison to all other individuals, in both the hips and the knees. However, while the left side had the highest percentage of joints affected in all other individuals, in Group 4 the right side had a higher percentage of joints affected than the left side. This pattern was similar to that seen in the sample from Castledyke South, where Group 4 females had a higher percentage of right lower limb joints affected than left lower limb joints.

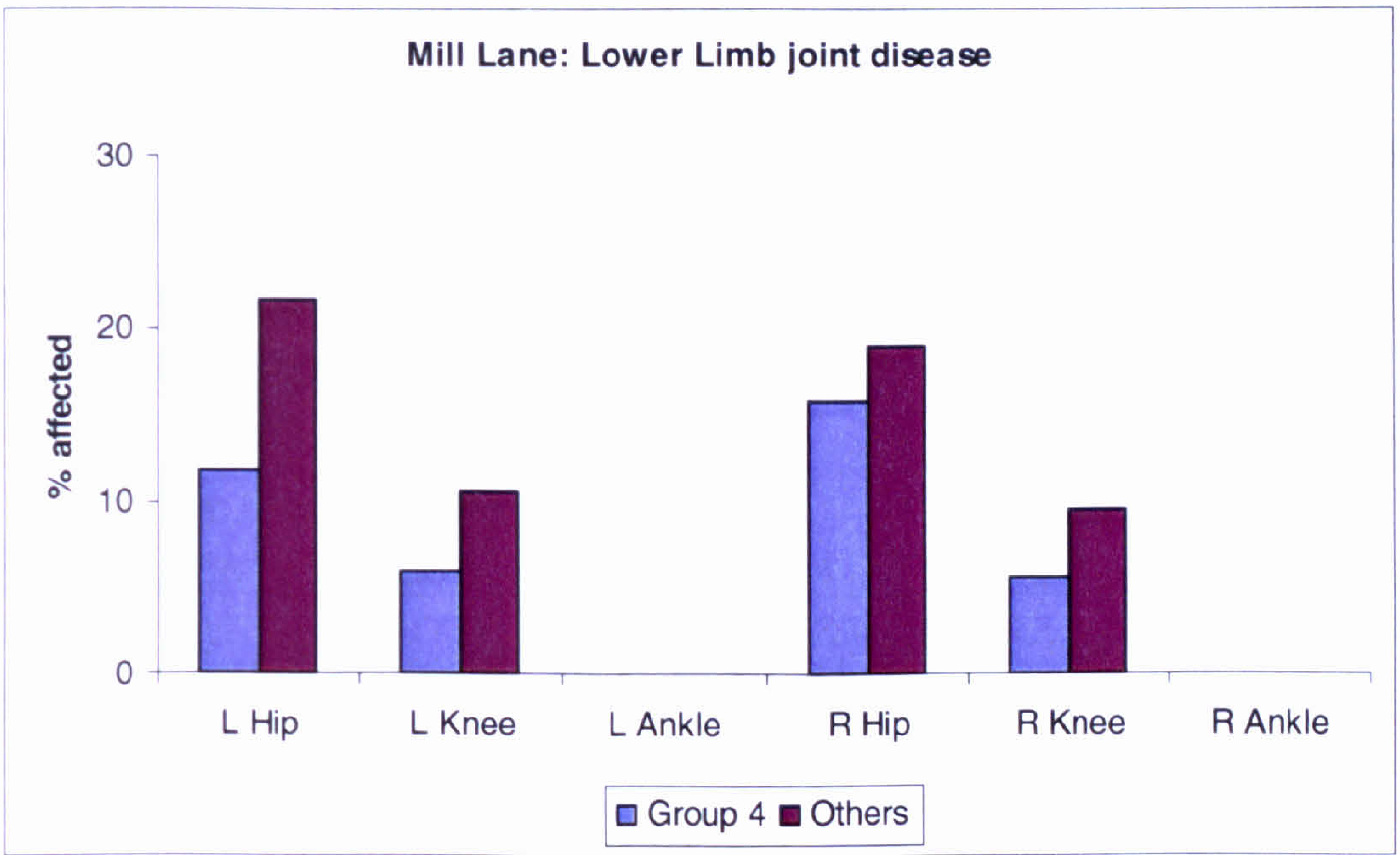


Figure 4.3.2g: The percentage of joints from the lower limb with osteoarthritis or possible osteoarthritis in Group 4 and all other individuals from Norton Mill Lane.

4.3.3 Bamburgh

From the total sample of 40 individuals examined from Bamburgh, 30 individuals (75%) had porosity and osteophytes, of which 10 individuals (25% of the total sample) also had eburnation in one or more joints. Tables showing the number and percentage of each joint surface observed, and the number and percent affected by porosity and osteophytes (?OA), porosity, osteophytes and eburnation (OA) on the left and right sides of the upper and lower limbs are presented in Appendix 2.3

In the upper limb, the percentage of right side joints with possible osteoarthritis was equal to or greater than the percentage of left side joints, for all elements. Other than in the distal humerus, the percentage of right side joints affected by osteoarthritis was greater than the percentage of left side joints. The percentage of joints affected was higher than that seen at Norton Mill Lane, and more similar to the frequencies seen at Castledyke South.
In the lower limb, the acetabulum, distal femur and proximal fibula all had a higher percentage of left side joints affected by possible osteoarthritis. However, the percentage of joints observed that were affected by osteoarthritis was greater in the right side than the left in all the joints where osteoarthritis was observed.

Table 4.3.3a shows the number of individuals present of each sex, the average number of functional joints present for observation in the upper and lower limbs, and the average number affected by osteoarthritis and possible osteoarthritis. The number of joints from each sex is given in brackets.

Sex	No. of Sk	Upper Limb			Lower Limb		
		Present	**OA**	**?OA**	**Present**	**OA**	**?OA**
Female	17	4.8 (77)	0.4 (6)	1.8 (28)	4.8 (82)	0.2 (3)	2.2 (38)
Male	23	5.1 (118)	0.6 (14)	2.9 (67)	5 (116)	0.2 (5)	2.7 (61)

Table 4.3.3a: The number of females and males with joints present and the average number of joints present, with OA and with possible OA in the upper and lower limbs. The number of joints present is given in brackets.

In both the upper and lower limb, and both sexes, only individuals who had joints with possible osteoarthritis (?OA) also had definite osteoarthritis (OA). For both the upper and lower limbs, males had an equal or greater average number of joints affected than females. The patterns of OA in the lower limb were more even between the sexes, with only a slightly higher average number of joints affected with possible osteoarthritis in the males. In both the upper and lower limbs, there were more joints present from males than from females, a fact that may be the cause of the apparently higher levels of osteoarthritis in males.

i) Osteoarthritis, Age and Sex

Table 4.3.3b shows the percentage of joints from both sides of the upper and lower limbs affected with osteoarthritis (OA, where eburnation was observed in the joint), possible osteoarthritis (?OA, where porosity and osteophytes were observed), and the percentage that were not affected (None) from females and males from each of the age groups in the Bamburgh sample. The number of joints present and affected by changes are given in brackets

Age Group	Female OA	Female ?OA	Female None	Male OA	Male ?OA	Male None
Young	0 (0)	0 (0)	74 (67)	0 (0)	0 (0)	70 (63)
Young /Middle	0 (0)	7 (2)	17 (5)	0 (0)	0 (0)	57 (34)
Middle	0 (0)	12 (22)	43 (77)	1 (2)	23 (34)	55 (82)
Older	6 (12)	34 (70)	38 (79)	5 (19)	45 (161)	18 (66)
Adult	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	40(12)

Table 4.3.3b: The percentage of joints from both sides of the upper and lower limbs, in each age group affected by OA, possible OA, not affected in females and males. The number of joints in each group is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

There were no joints available for observation from females in the Adult age group. This Table shows that in both males and females, the percentage of joints affected by osteoarthritis and possible osteoarthritis increased with age. In both sexes the increase in OA with age was statistically significant (chi squared, females $p= 0.01$, males $p=0.01$). The results for possible OA also produced p values of less than 0.01 for both sexes, suggesting that the changes associated with possible OA also increased significantly with increasing age. As both OA and possible OA were correlated with increasing age, it is reasonable to pool these data for the examination of OA and social status, without the risk of obscuring patterns that may be due to differences in social status.

ii) Osteoarthritis and Status

Tables showing the number (in brackets) and the percentage of joints from the left and right sides of the upper and lower limbs that were affected by osteoarthritis and possible osteoarthritis, and the percentage and number of individuals affected from each of the burial artefact groups in the skeletal sample from Bamburgh are presented in Appendix 2.3.

Group C had the highest percentage of individuals with OA and equal highest percentage of individuals with ?OA, and that all the joints with OA from Groups B and D were from the same individual. Groups C and D had the highest percentage of individuals with ?OA, but the patterns of joints affected in these two groups were different. The number of individuals with ?OA was considerably higher than the number with OA. Figure 4.3.3a shows the percentage of joints from the left and right upper limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Bamburgh.

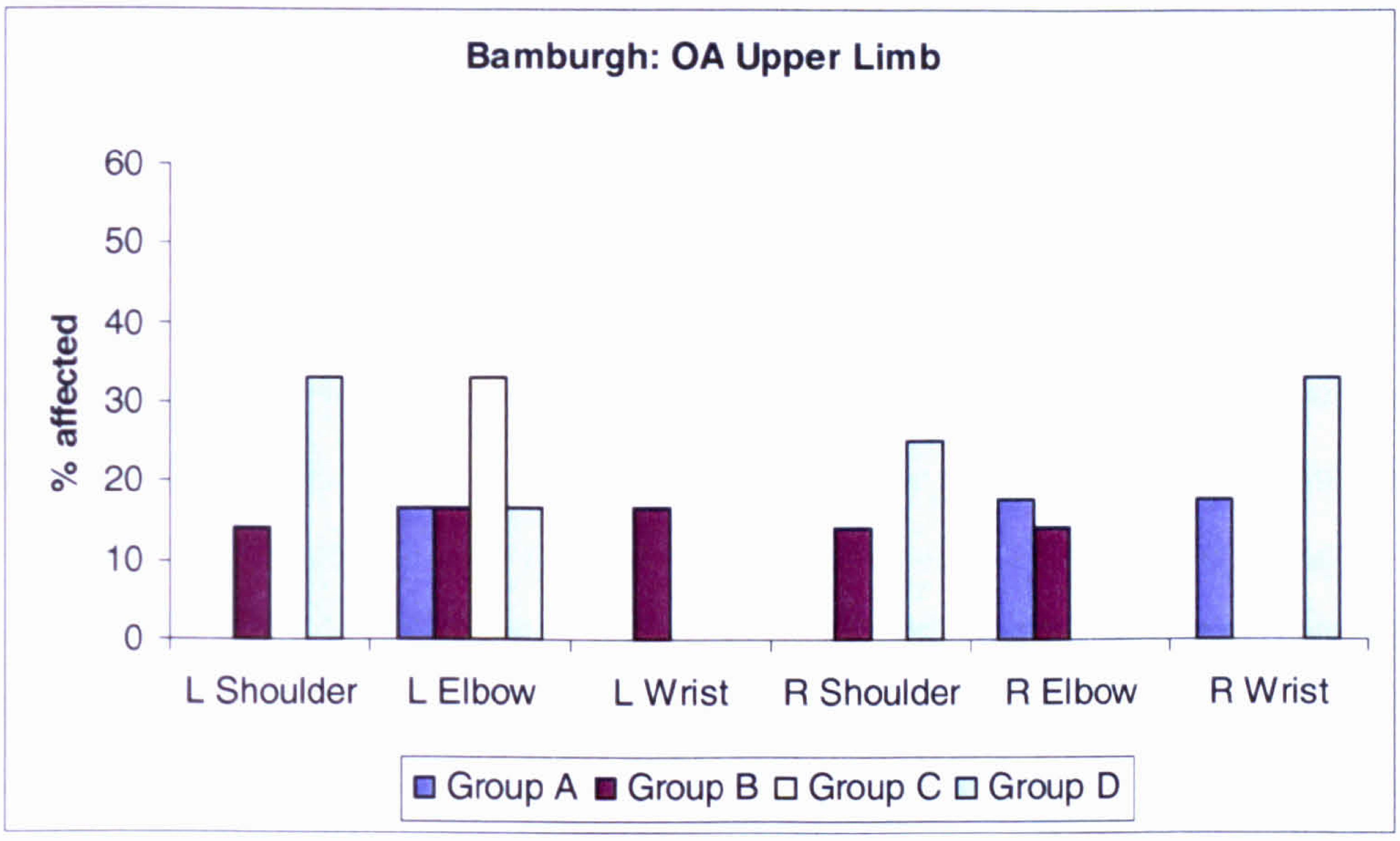


Figure 4.3.3a: The percentage of joints from the upper limb with osteoarthritis from each of the artefact groups at Bamburgh. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C – multiple animal bones, Group D – Multiple iron objects.

All four of the artefact groups had individuals with joints from the upper limb that were affected by osteoarthritis, but there was variation in the location and prevalence of the condition between the artefact groups. Group B had the widest range of joints involved, with only the right wrist being unaffected, but all these joints were from the same individual, while the individuals from Group C were only affected in the left elbow. Figure 4.3.3b shows the percentage of joints that were affected by possible osteoarthritis.

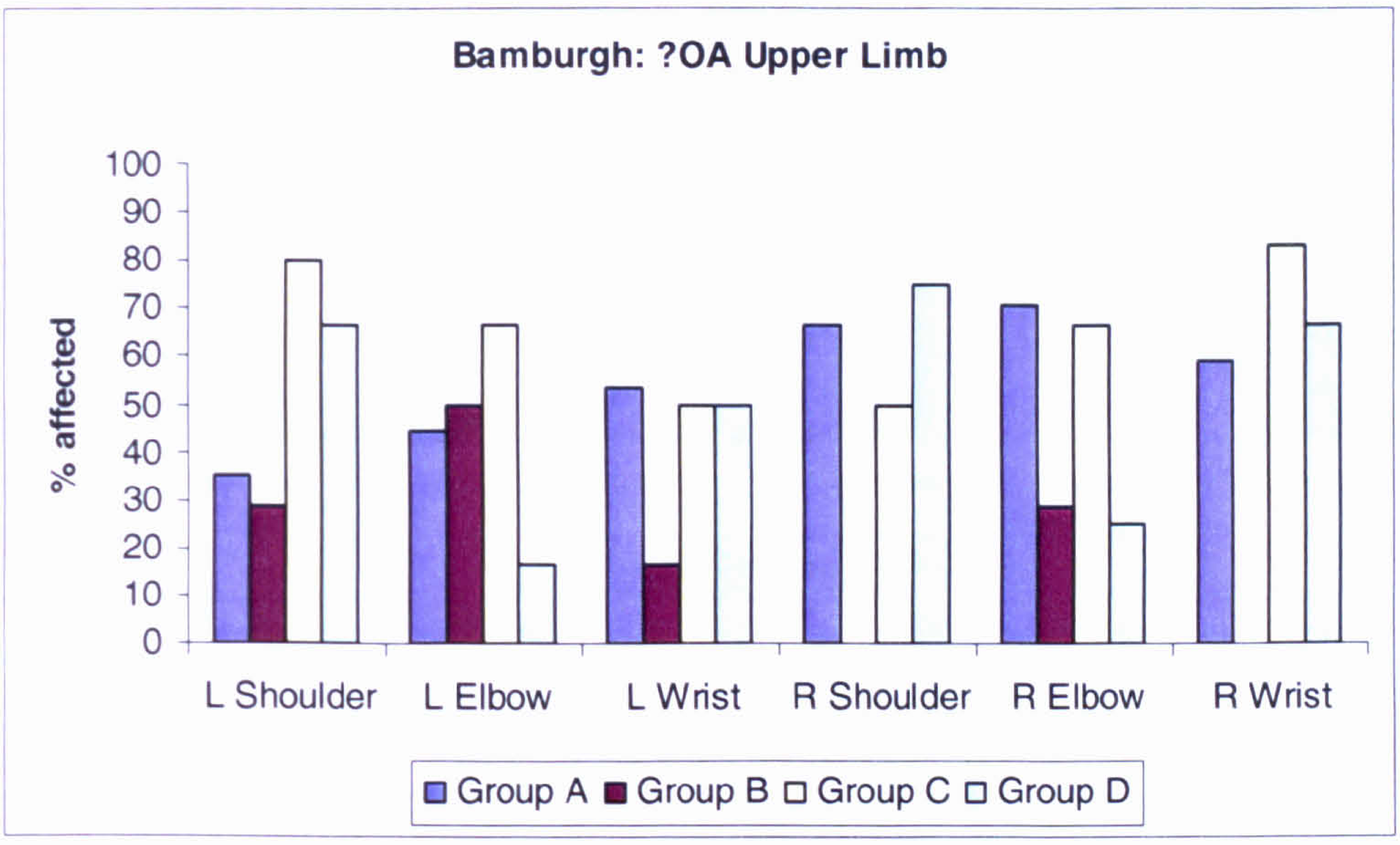


Figure 4.3.3b: The percentage of joints from the upper limb with possible osteoarthritis from each of the artefact groups at Bamburgh. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

This figure shows that the percentage of joints affected by possible osteoarthritis was much higher than osteoarthritis, and that there was also variation between the artefact groups. Group A individuals had a lower percentage of joints from the left side affected than those from the right side in the shoulder, elbow and wrist, and also had relatively high percentage of joints affected overall. Group B was the only group where there were joints that were unaffected, Group D had the lowest percentage of elbow joints affected and Group C had the highest percentage of left shoulder, left elbow and right wrist joints affected. As Group C consisted entirely of males and the majority of Group D individuals were females, it is possible that some of the variation between the groups was due to sex. Therefore the results for Group C were compared with all other males, and the results from Group D were compared with those from all other females. The pattern of joints affected in Group A appeared to be different to that seen in the other groups, so this group was compared with all other individuals. As the numbers of joints involved were small and both OA and possible OA were correlated with increased age, the prevalences of both osteoarthritis and possible osteoarthritis were pooled, in order to increase sample size. Pooling these data did not obscure the differences between the artefact groups identified in figures 4.3.3a and b.

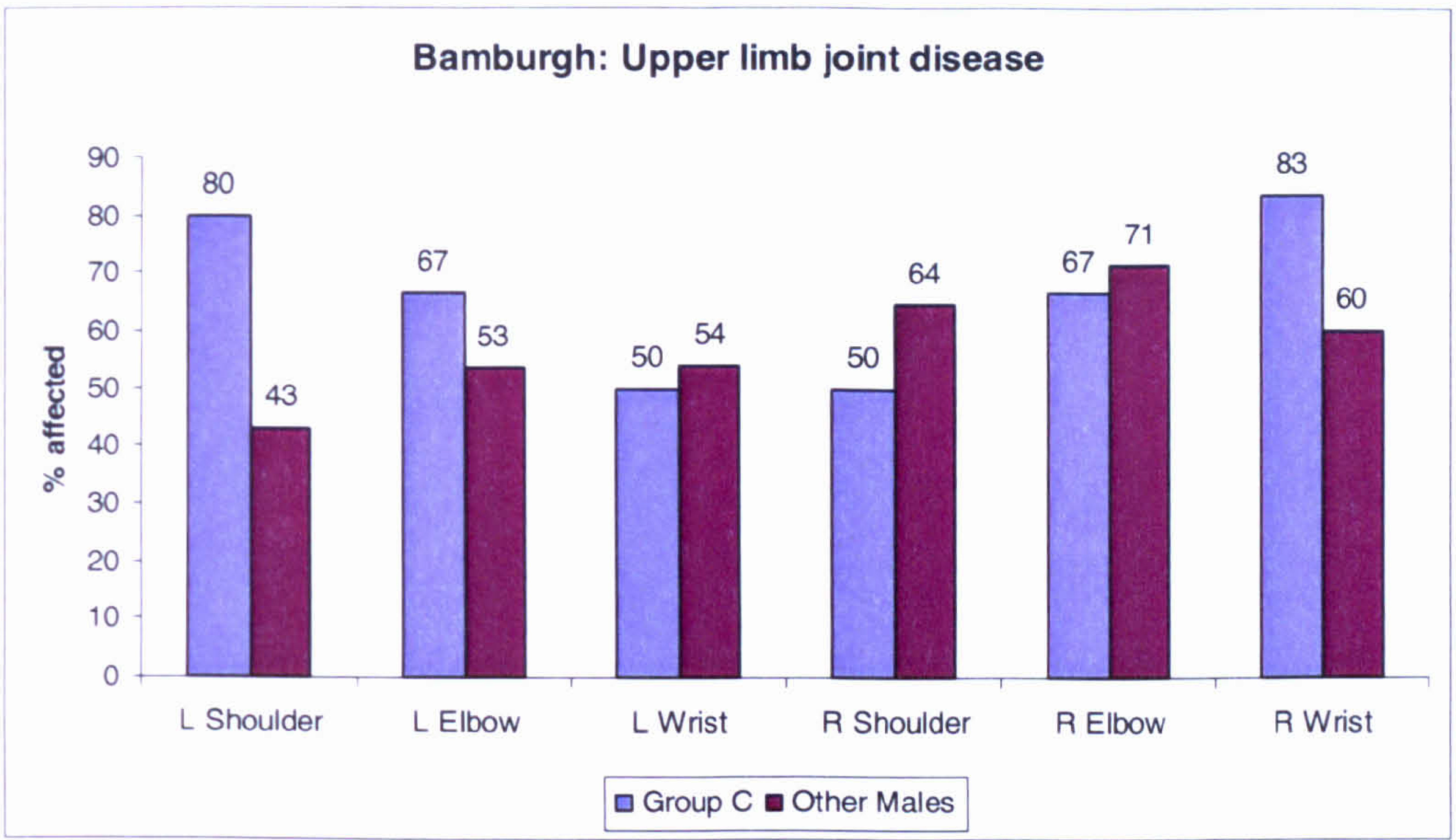


Figure 4.3.3c: The percentage of upper limb joints from Group C and from all other males that were affected by osteoarthritis or possible osteoarthritis.

Figure 4.3.3c shows the percentage of joints from the upper limb affected in Group C and in all other males from Bamburgh. The percentage of left shoulder, left elbow and right wrist joints with changes was greater in Group C than in all other males, with the difference between the percentages of left shoulder joints being significantly higher in Group C (chi squared $p = 0.02$). However, the prevalence of changes was higher in the left wrist, right shoulder and right elbow from all other males than in Group C.

Figure 4.3.3d shows the percentage of joints from the upper limb that were affected by osteoarthritis or possible osteoarthritis from individuals from Group D, compared with all other females. Other than in the elbow joints, the percentage of joints affected from Group D was higher than that seen in all other females from Bamburgh, and the percentage of shoulder joints affected was significantly higher in Group D (chi squared $p= 0.02$). These striking differences between Group D and all other females suggest that there is some factor leading to higher levels of joint disease in the upper limb in this artefact group.

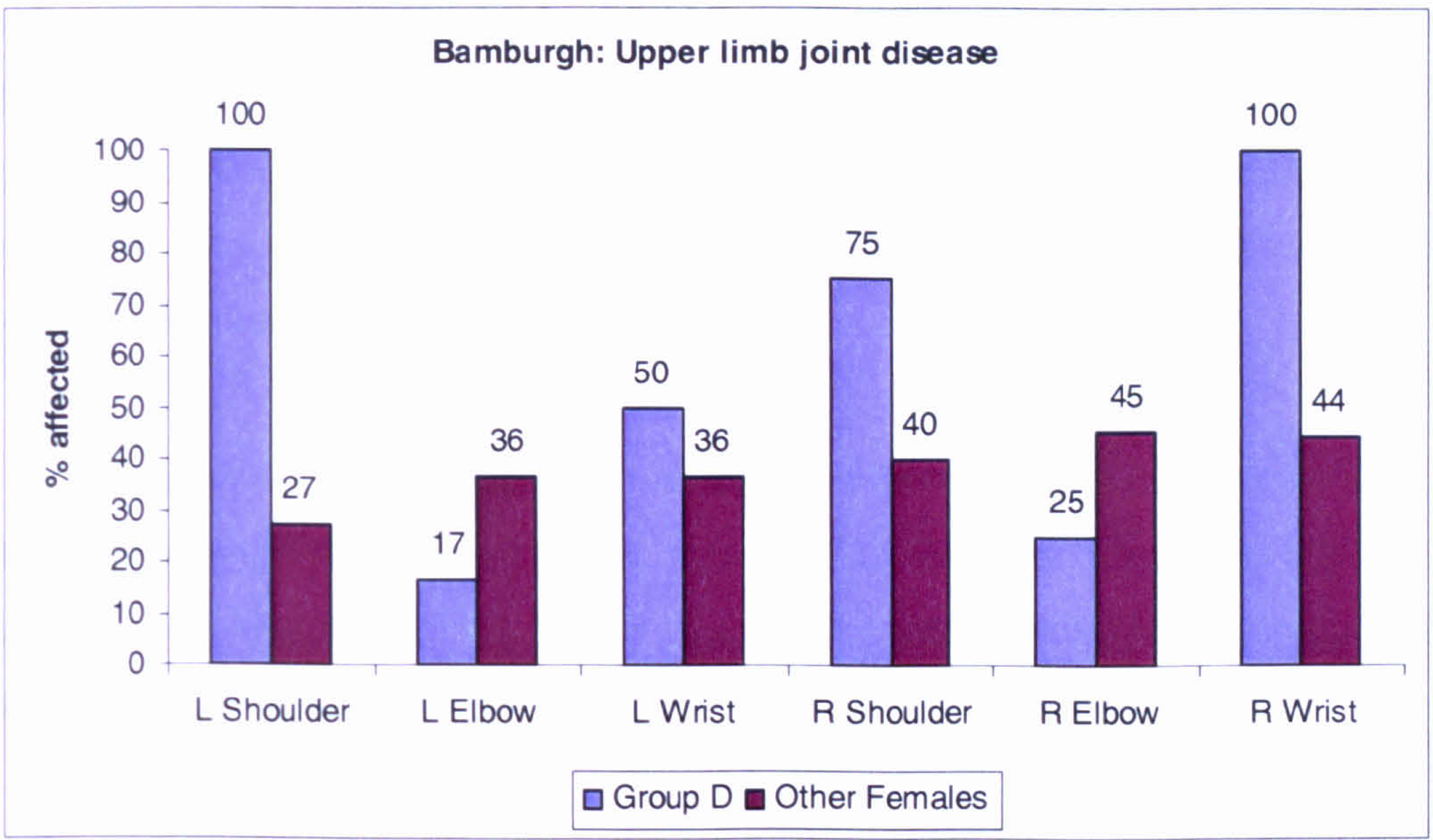


Figure 4.3.3d: The percentage of upper limb joints from Group D and from all other females that were affected by osteoarthritis or possible osteoarthritis.

Figure 4.3.3e shows the percentages of upper limb joints affected by changes from Group A individuals and all other individuals from Bamburgh.

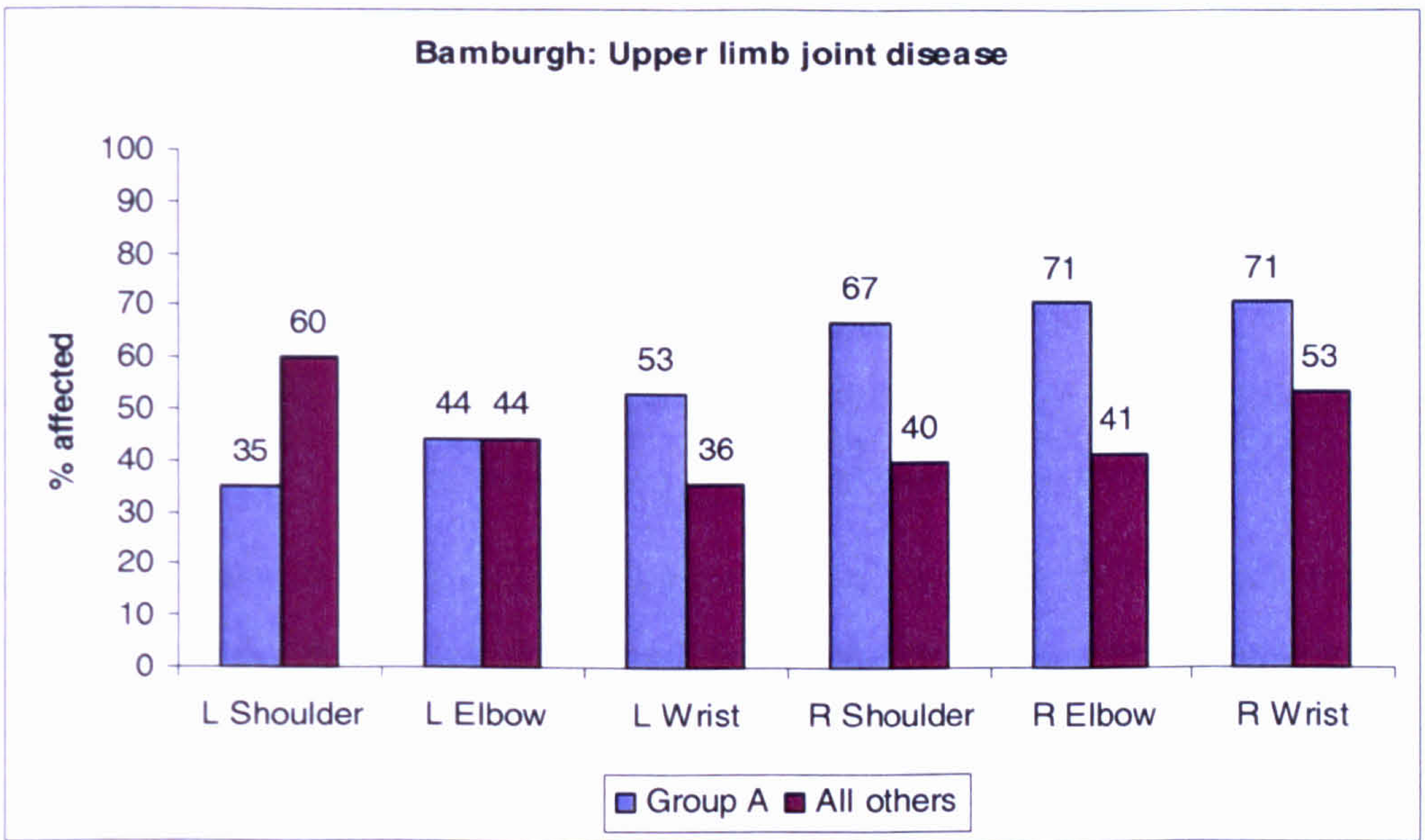


Figure 4.3.3e: The percentage of upper limb joints from Group A and from all other individuals that were affected by osteoarthritis or possible osteoarthritis.

The percentage of joints affected from Group A was higher on the right side for all three joints, and higher than that seen in all other individuals. The percentage of joints affected in Group A was significantly higher than that seen in the rest of the sample for the right shoulder (chi squared right shoulder p=0.01), but conversely the percentage of left shoulder joints affected was significantly higher in all other individuals (p= 0.001). These results suggest that Group A individuals, those buried without any artefacts, were at a higher risk of developing osteoarthritis in the right side of the upper limb than the rest of the skeletal sample from Bamburgh.

The percentage of individuals with ?OA was similar in the lower limb to the upper limb, but the pattern of OA was rather different. Figure 4.3.2f shows the percentage of joints from the left and right lower limbs from both sexes that were affected by osteoarthritis in each of the artefact groups from Bamburgh

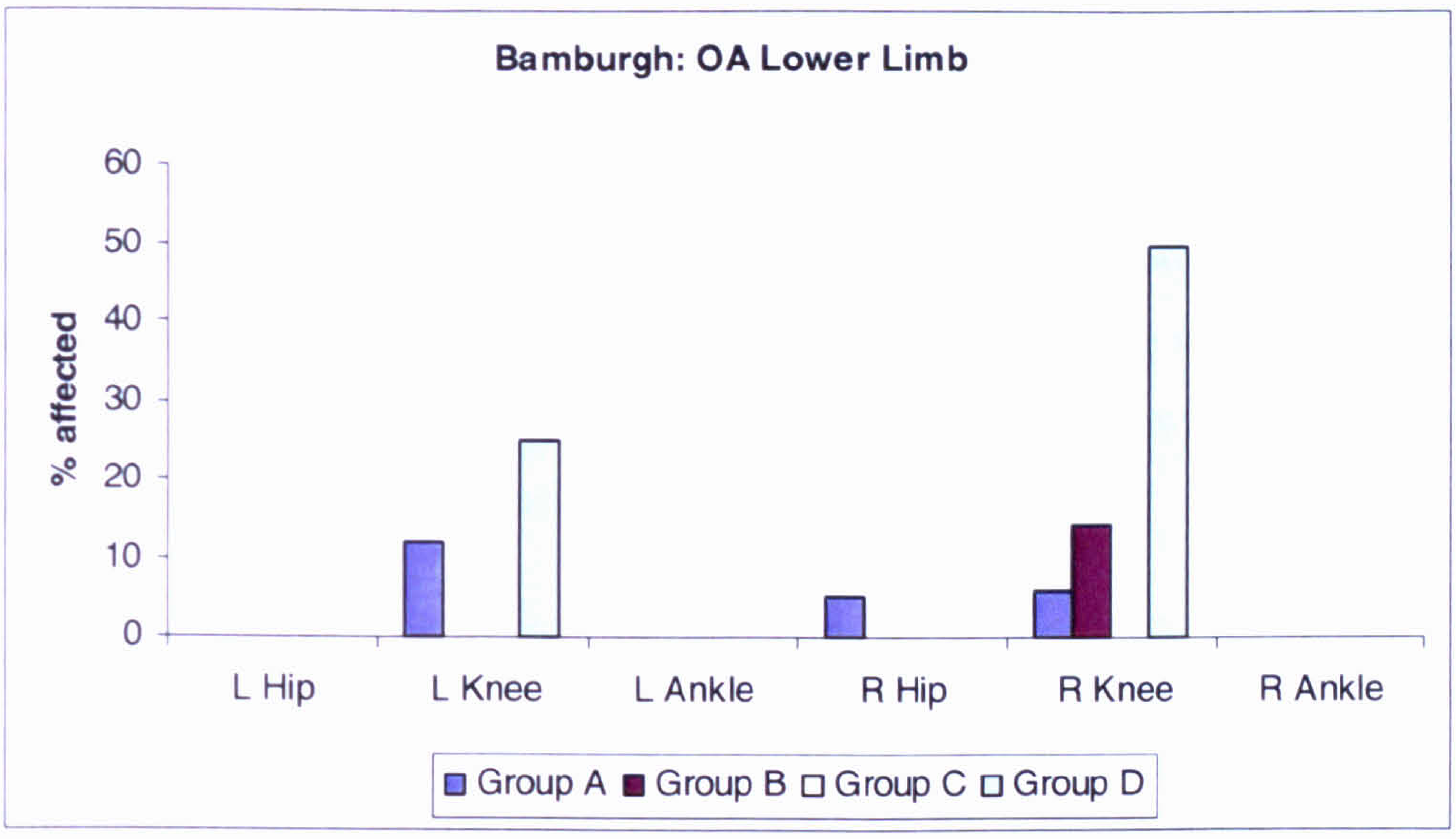


Figure 4.3.3f: The percentage of joints with osteoarthritis in the lower limb from each of the artefact groups at Bamburgh. . Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

There were no lower limb joints affected from Group C, and only the right knee was affected in Group B. Overall, few lower limb joints were affected, with the highest prevalence seen in the knees of Group D individuals. Figure 3.3.3g shows the percentage of joints from the lower limb affected by possible osteoarthritis

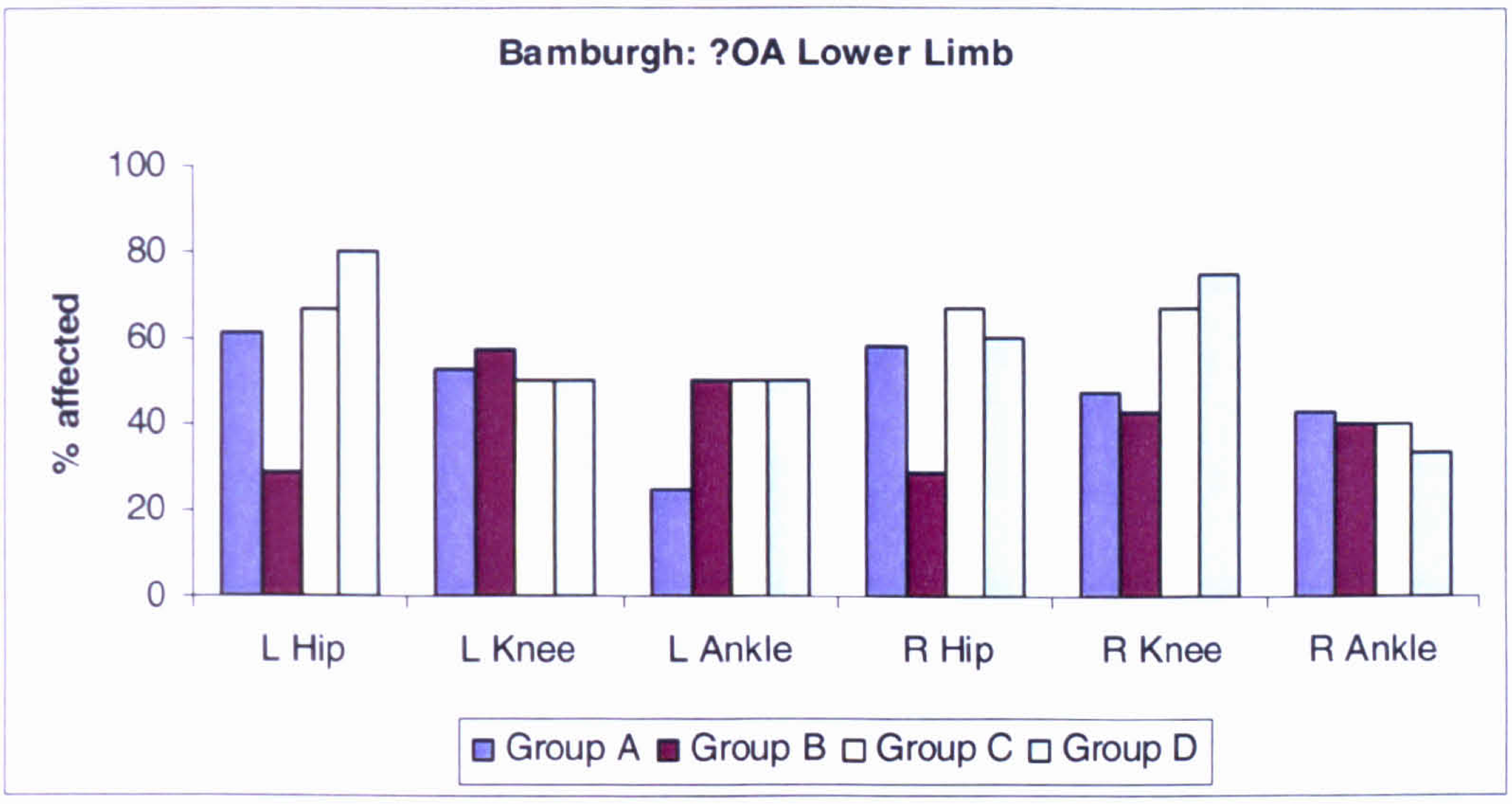


Figure 4.3.3g: The percentage of joints with osteoarthritis in the lower limb from each of the artefact groups at Bamburgh. . Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

In contrast with the prevalence of osteoarthritis, possible osteoarthritis was much more frequent in the lower limb, with the percentages of joints involved being quite similar between the artefact groups, particularly in the knees. However, there were some apparent differences; the percentage of hip joints affected was low in Group B while Group D had the highest percentage of left hip and right knee joints affected.

Due to the small number of joints affected by osteoarthritis, in order to examine the prevalence of joint disease in more detail between the artefact groups, the data for osteoarthritis and possible osteoarthritis were pooled for the comparisons between groups. Figure 4.3.3h shows the percentage of lower limb joints affected by changes in Group C and all other males from Bamburgh. As was seen for the results from the upper limb, the percentage of lower limb joints affected were similar, particularly in the right knee and right ankle, but in the hip joints the percentages of Group C individuals were higher than those seen in all other males.

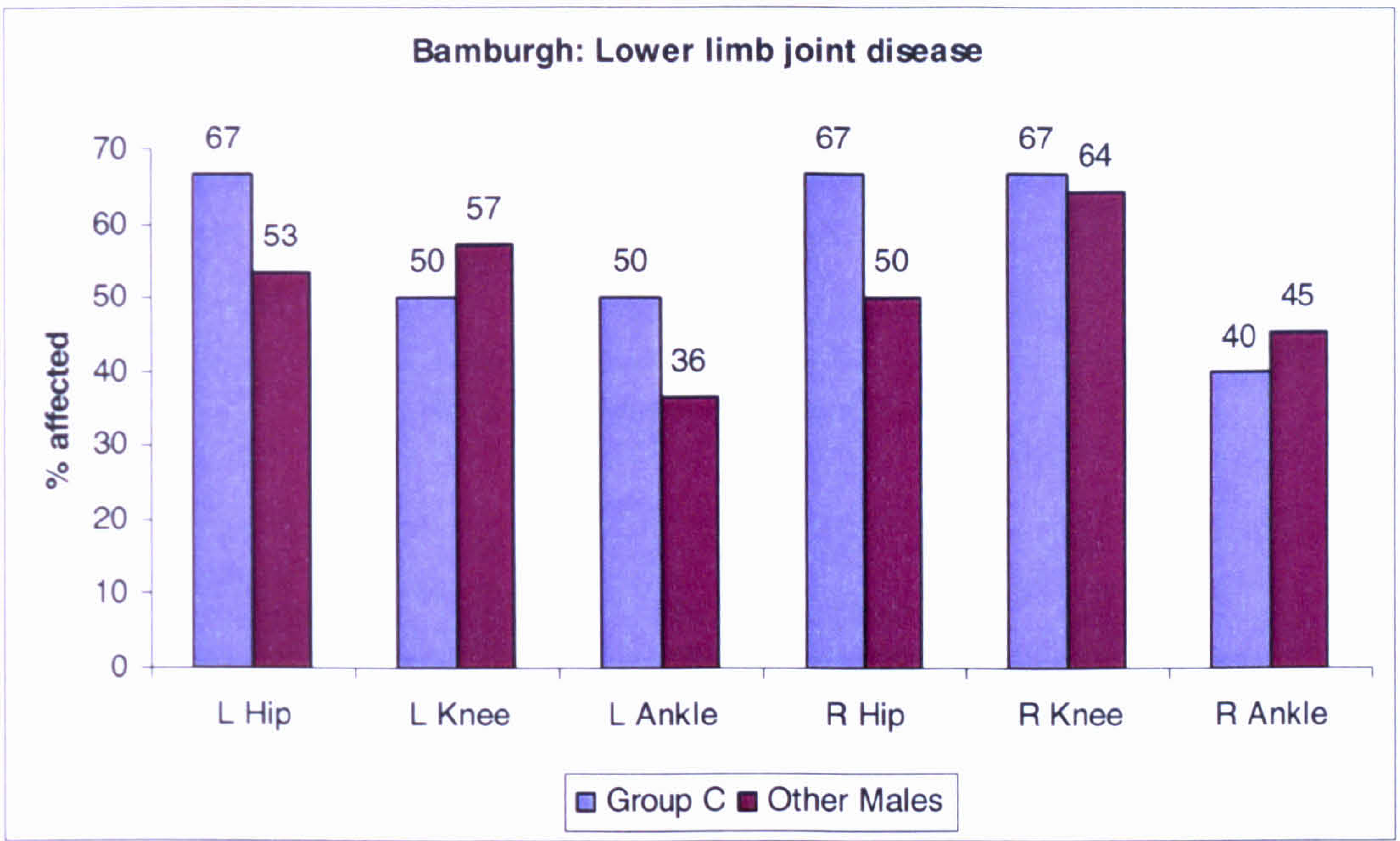


Figure 4.3.3h: The percentage of lower limb joints with osteoarthritis or possible osteoarthritis from Group C and from all other males at Bamburgh.

Figure 4.3.3i shows the percentage of joints affected from the lower limb in Group D and in all other females. Group D had equal or higher percentages of joints affected in comparison with all other females, but only the difference in the percentage of right knee joints involved was statistically significant (chi squared p= 0.04).

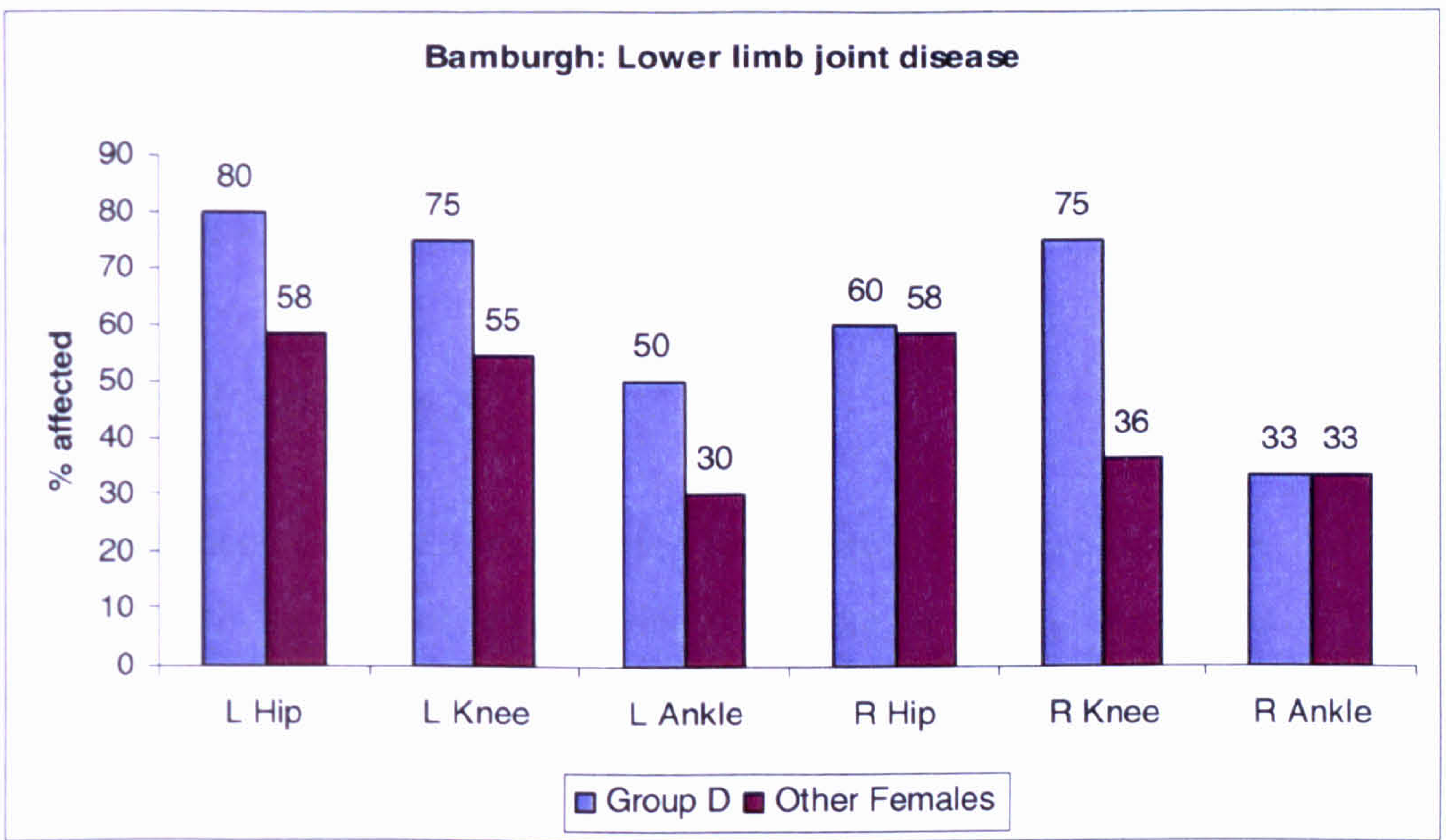


Figure 4.3.3i: The percentage of lower limb joints with osteoarthritis or possible osteoarthritis from Group D and from all other females at Bamburgh.

Figure 4.3.3j shows the percentage of lower limb joints affected by changes in Group A and all other individuals. Again, the differences were not as dramatic as those seen in the upper limb, with only the results for the left ankle showing any great difference, although this was not statistically significant (chi squared p= 0.07).

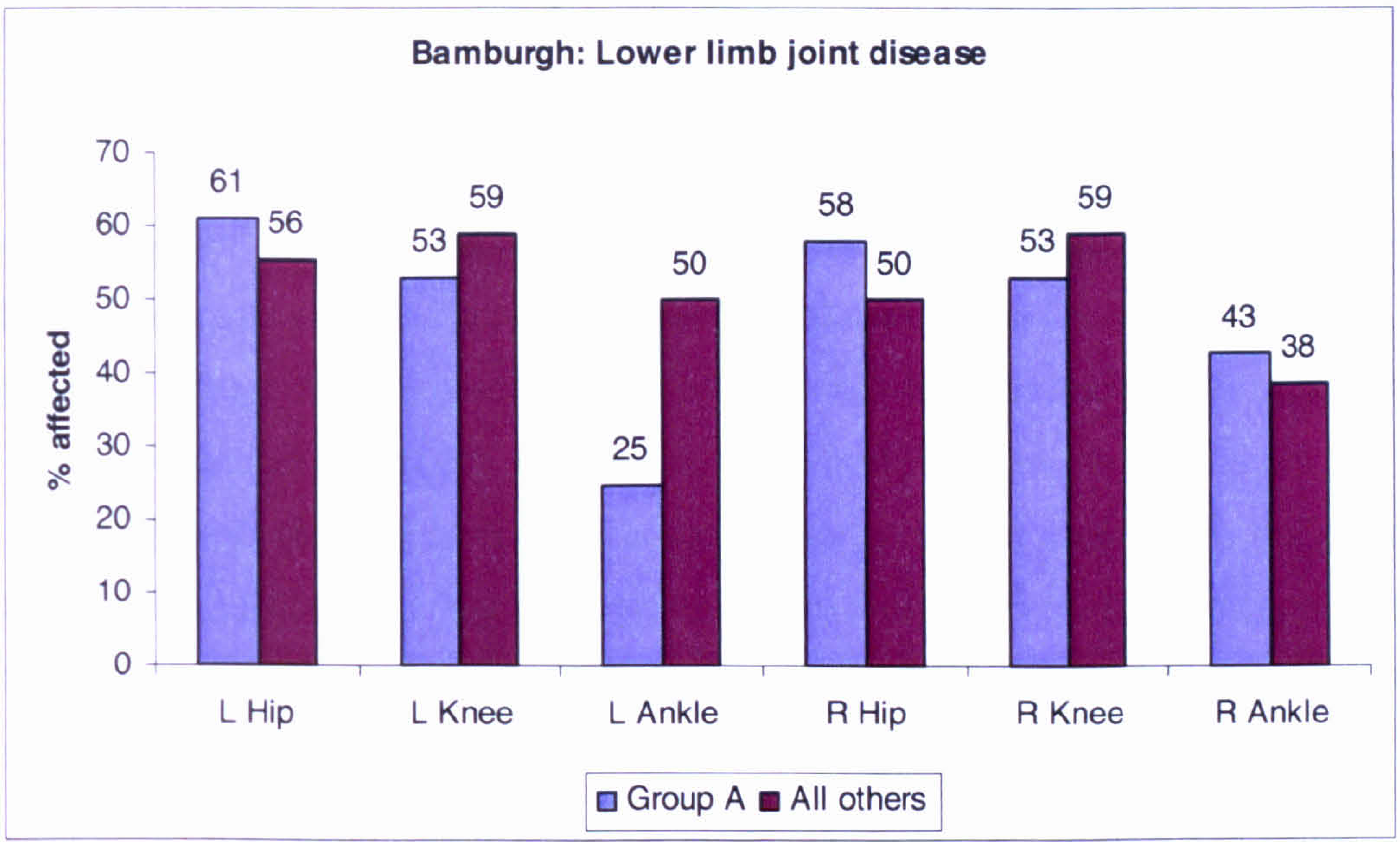


Figure 4.3.3j: The percentage of lower limb joints with osteoarthritis or possible osteoarthritis from Group A and from all other individuals at Bamburgh.

These results show that, in the Bamburgh sample, the majority of differences in the prevalence of degenerative changes to the joints between the artefact groups were seen in the upper limb, with the patterns of joint disease in the lower limb being much more homologous between the artefact groups.

4.3.4 Norton Bishopsmill

Of the 40 individuals examined from Norton Bishopsmill, 19 individuals (46%) had possible osteoarthritis (porosity and osteophytes) in one or more joint surfaces, of which 9 individuals (23% of the total sample) also had eburnation in one or more joints. Tables showing the number and percentage of each joint surface observed, and the number and percent affected by porosity and osteophytes (?OA), porosity, osteophytes and eburnation (OA) on the left and right sides of the upper and lower limbs are presented in Appendix 2.4. Osteoarthritis was seen on the left and right sides of the distal humerus, distal ulna and proximal radius, and on the right side of the distal radius, but the numbers of joint surfaces affected by osteoarthritis and possible osteoarthritis were small, and much lower than those seen at Castledyke South. The percentages of joints that were affected were even lower than those seen at the nearby site of Norton Mill Lane. In the upper limb, the percentage of joints observed with possible OA, and the percentage of joints showing OA was equal to or greater than the percentage of joints from the left side in all elements.

In the lower limb, osteoarthritis was seen on both the acetabulum and femoral head, and in the right distal femur, patella and proximal tibia. Possible osteoarthritis was seen in all of the lower limb joints with the exception of the proximal and distal fibula. In the lower limb, the percentage of joints observed with possible osteoarthritis was greater on the left side in the acetabulum and patella and equal in the femoral head and the distal tibia. The percentage of joints showing osteoarthritis was greater on the left acetabulum, but greater on the right side in all other joints where osteoarthritis was observed. As in the upper limb, the number of joints affected was very small, even though the number of joints present was comparable with the number examined from Norton Mill Lane and Bamburgh.

Table 4.3.4a shows the number of individuals present of each sex, the average number of functional joints present for observation in the upper and lower limbs, and the average number affected by osteoarthritis and possible osteoarthritis. The number of joints from each sex is given in brackets.

Sex	No. of Sk	Upper Limb			Lower Limb		
		Present	**OA**	**?OA**	**Present**	**OA**	**?OA**
Female	17	3.8 (50)	0.3 (4)	0.7 (9)	5.2 (89)	0.2 (4)	0.6 (10)
Male	22	3.5 (73)	0.2 (4)	0.8 (16)	5.3 (112)	0.3 (6)	1 (22)

Table 4.3.4a: The number of females and males with joints present and the average number of joints present, with OA and with possible OA in the upper and lower limbs. The number of joints present is given in brackets.

In the upper limb, males had a higher average number of joints with possible osteoarthritis, and in the lower limb males had a higher average number of joints with osteoarthritis and possible osteoarthritis.

i) Osteoarthritis, Age and Sex

Table 4.3.4 b shows the percentage and number in brackets, of joints from both sides of the upper and lower limbs affected with osteoarthritis, possible osteoarthritis and the percentage that were not affected in females and males from each of the age groups in the Norton Bishopsmill skeletal sample.

Age Group	Female			Male		
	OA	?OA	None	OA	?OA	None
Young	1 (1)	1 (1)	48 (73)	0 (0)	0 (0)	34 (31)
Young/ Middle	0 (0)	0 (0)	77 (23)	0 (0)	2 (2)	38 (45)
Middle	0 (0)	3 (6)	46 (97)	3 (4)	6 (9)	57 (86)
Older	9 (11)	13 (16)	29 (34)	4 (9)	15 (35)	39 (93)
Adult	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	42 (25)

Table 4.5.3b: The percentage of joints from both sides of the upper and lower limbs, in each age group affected by OA, possible OA, not affected in females and males. The number of joints in each group is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

This table shows that in both sexes the percentage of joints affected by osteoarthritis and possible osteoarthritis increased with age, and this difference was significant for both sexes (chi squared, females p=0.02, males p=0.01). Therefore it is reasonable to pool the data for OA and possible OA without the risk of obscuring other patterns that may be due to differences in social status rather than age.

i) Osteoarthritis and Status

Tables showing the number (in brackets) and the percentage of joints from the left and right sides of the upper and lower limbs that were affected by osteoarthritis and possible osteoarthritis, and the percentage and number of individuals affected from each of the burial artefact groups in the skeletal sample from Bishopsmill are presented in Appendix 2.4. As the number of individuals with joints preserved from Groups B and C was very small, these groups were combined to increase the samples size and allow analysis of the results to be carried out. The percentage of individuals with OA in the upper limb was very similar between the artefact groups, but the joints affected were different. Group D had the highest percentage of individuals with ?OA. Figure 4.3.4a shows the percentage of joints from the left and right upper limbs from both sexes that were affected by osteoarthritis in each of the artefact groups. Individuals from all of the artefact groups were affected, but particularly those from Group A, although no individuals had osteoarthritis in either side of the shoulder. Only a single individual from Group D had osteoarthritis in the upper limb, in the right elbow joint, and the cases of osteoarthritis from Groups B and C were also from a single individual.

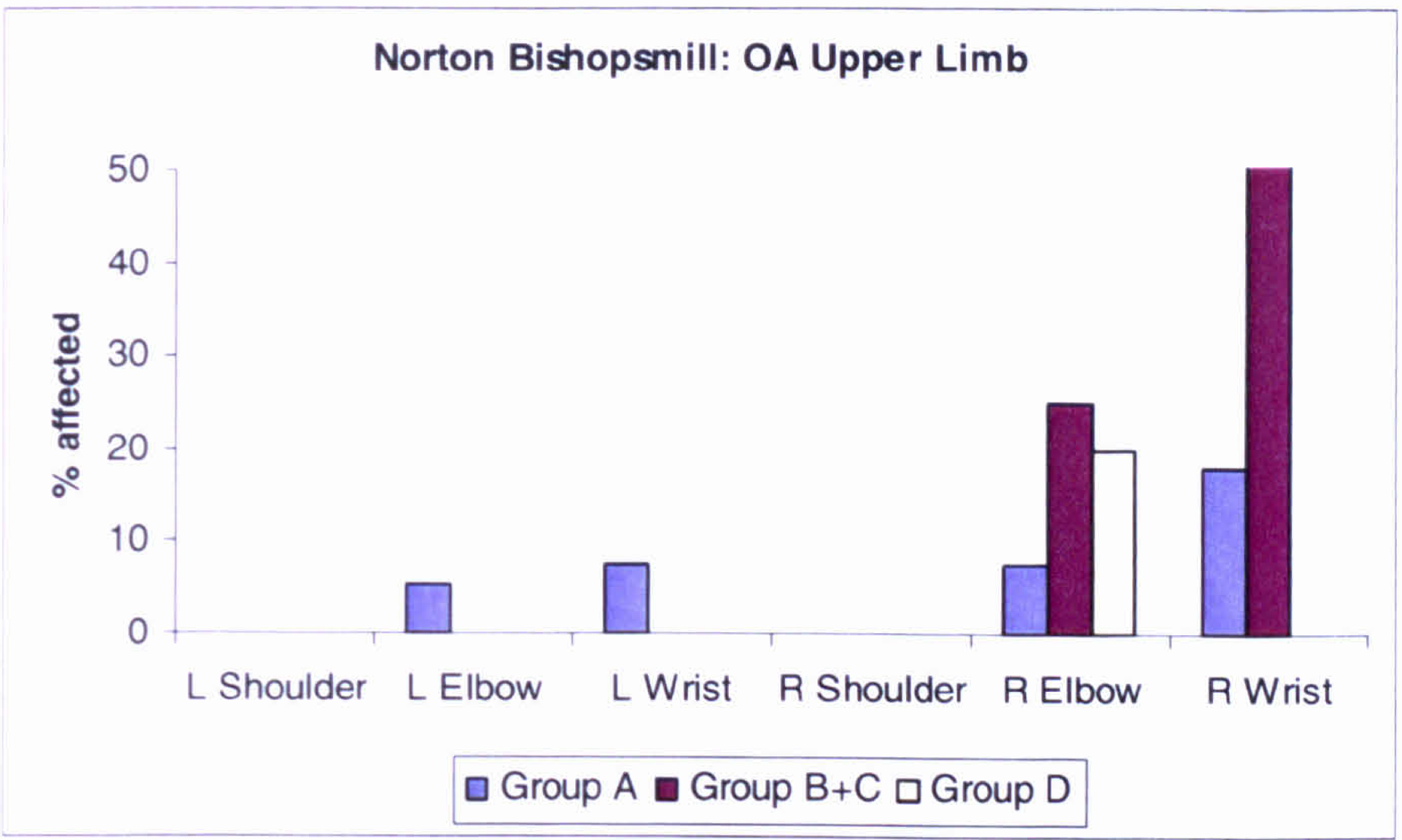


Figure 4.3.4a: The percentage of joints from the upper limb with osteoarthritis from each of the artefact groups at Norton Bishopsmill Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Figure 4.3.4b shows the percentage of joints from the left and right sides of upper limbs that were affected by possible osteoarthritis in the artefact groups from Norton Bishopsmill. The percentages of joints with possible osteoarthritis were higher than the percentages affected by osteoarthritis.

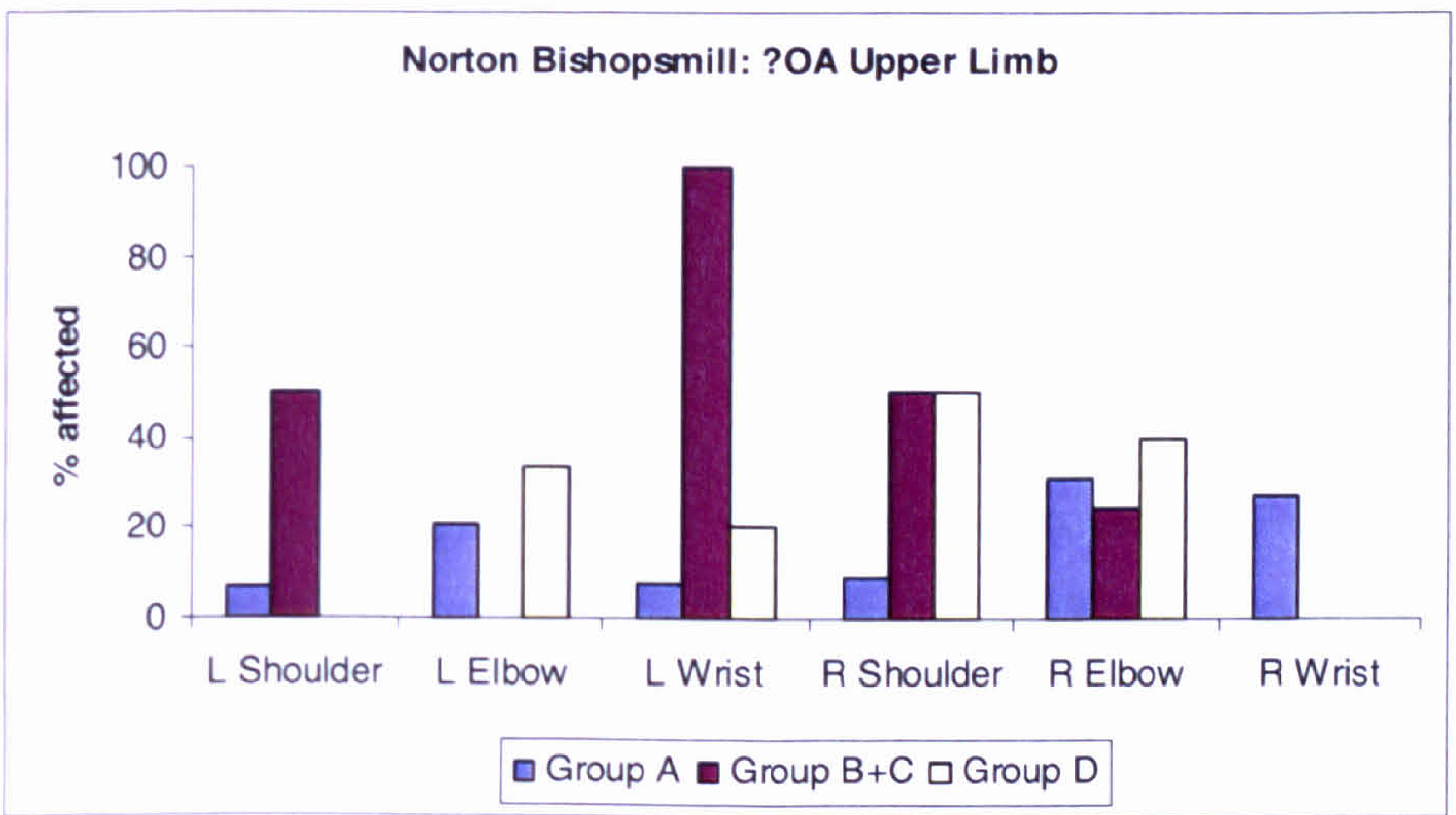


Figure 4.3.4b: The percentage of joints from the upper limb with possible osteoarthritis from each of the artefact groups at Norton Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Group A was the only group where all of the upper limb joints were affected, but the percentage of joints affected was generally lower than those seen in Groups B and C and Group D. As the number of individuals with OA in the upper limb from Groups B and C and Group D was small, in order to compare with Group A, cases of OA and ?OA were pooled to increase sample size. Figure 4.3.4c shows the percentage of joints with osteoarthritis or possible osteoarthritis in Group A, compared with those from all other individuals from Norton Bishopsmill.

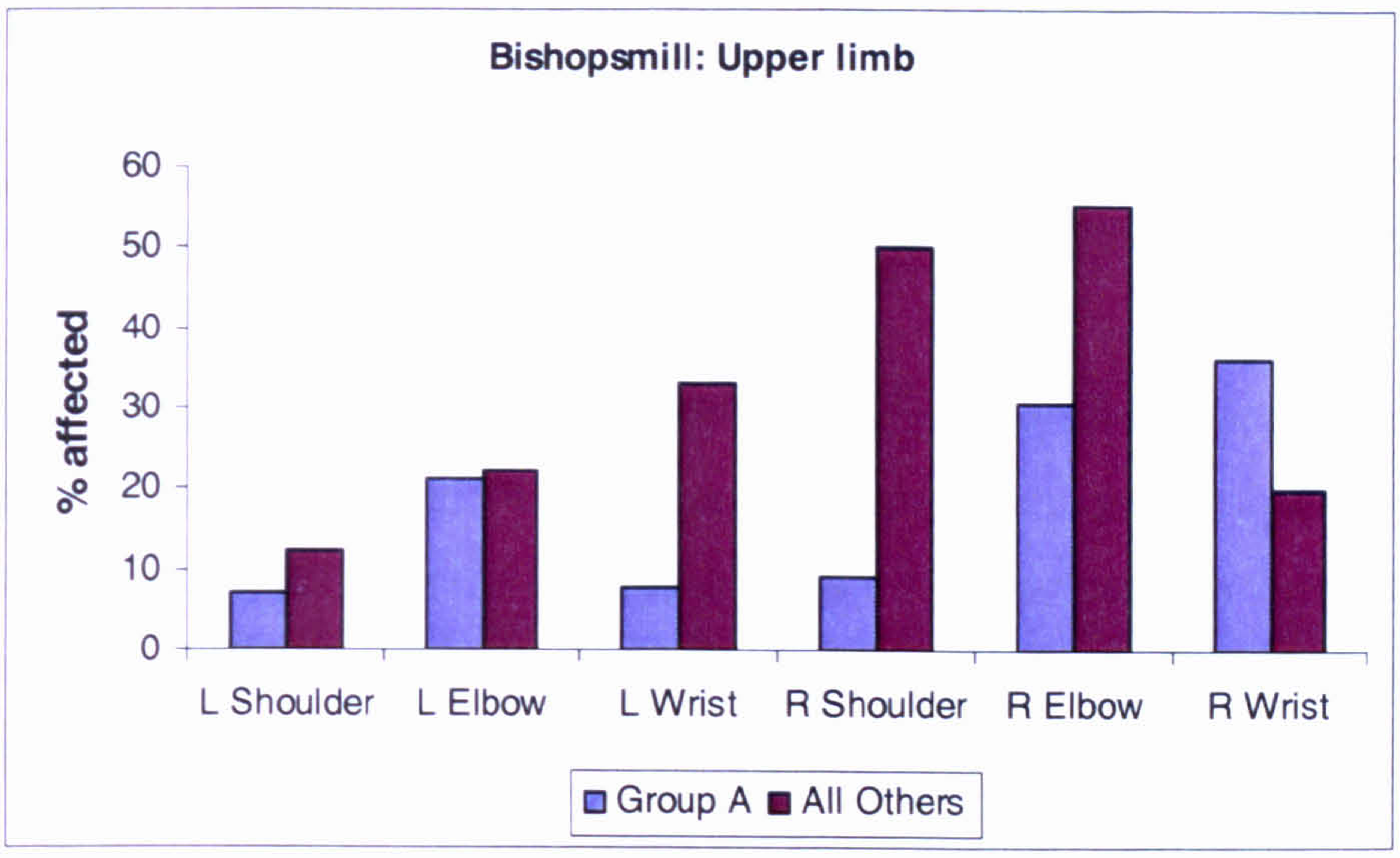


Figure 4.3.4c: The percentage of joints from the upper limb with OA or ?OA from Group A and all other individuals from Norton Bishopsmill.

From this figure it is apparent that the percentage of joints affected by changes was lower in Group A than in all other individuals, with the exception of the right wrist. The percentage of left wrist joints that were affected was significantly smaller in Group A than in all other individuals (chi squared $p = 0.01$), as were the differences in the right shoulder ($p = 0.001$), but the percentage of joints affected from the right wrist was significantly higher in Group A ($p = 0.00001$).

In the lower limb, only one individual from Group D had joints with OA, but four individuals had joints with ?OA. Figure 4.3.4d shows the percentage of lower limb joints from each artefact group that had osteoarthritis. Only the hip and right knee joints were affected, with the right hip and knee being the most frequently affected joints. The left hip was the only joint to be affected in Group D.

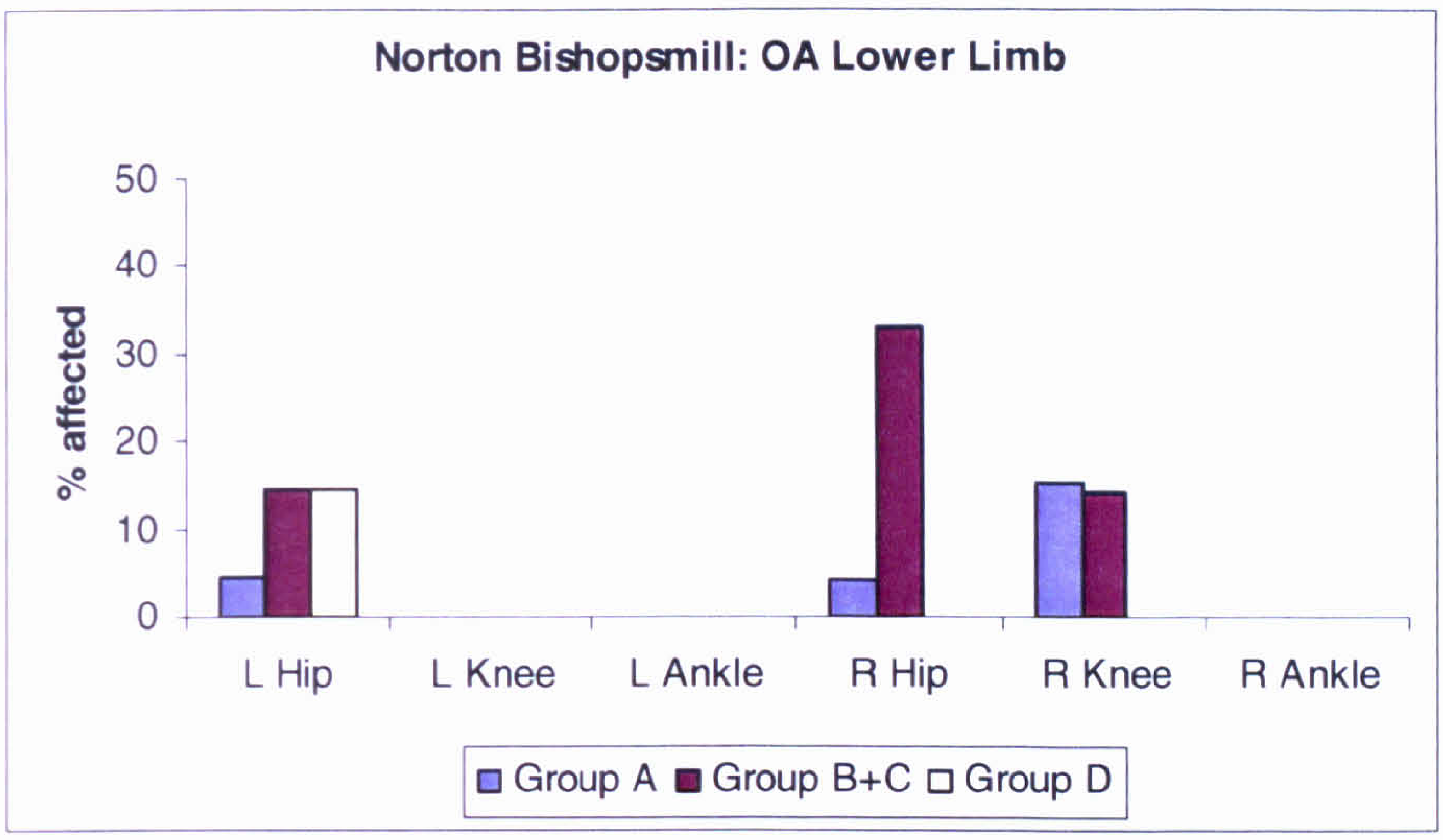


Figure 4.3.4d: The percentage of lower limb joints with osteoarthritis from Norton Bishopsmill. .Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Figure 4.3.4e shows the percentage of lower limb joints with possible osteoarthritis from Norton Bishopsmill. The prevalence of possible osteoarthritis was much higher than that observed for osteoarthritis; all of the lower limb joints were affected, with Group D individuals having the highest percentage of hip and right knee joints affected. Group A was the only group where both sides of the ankle joint were affected.

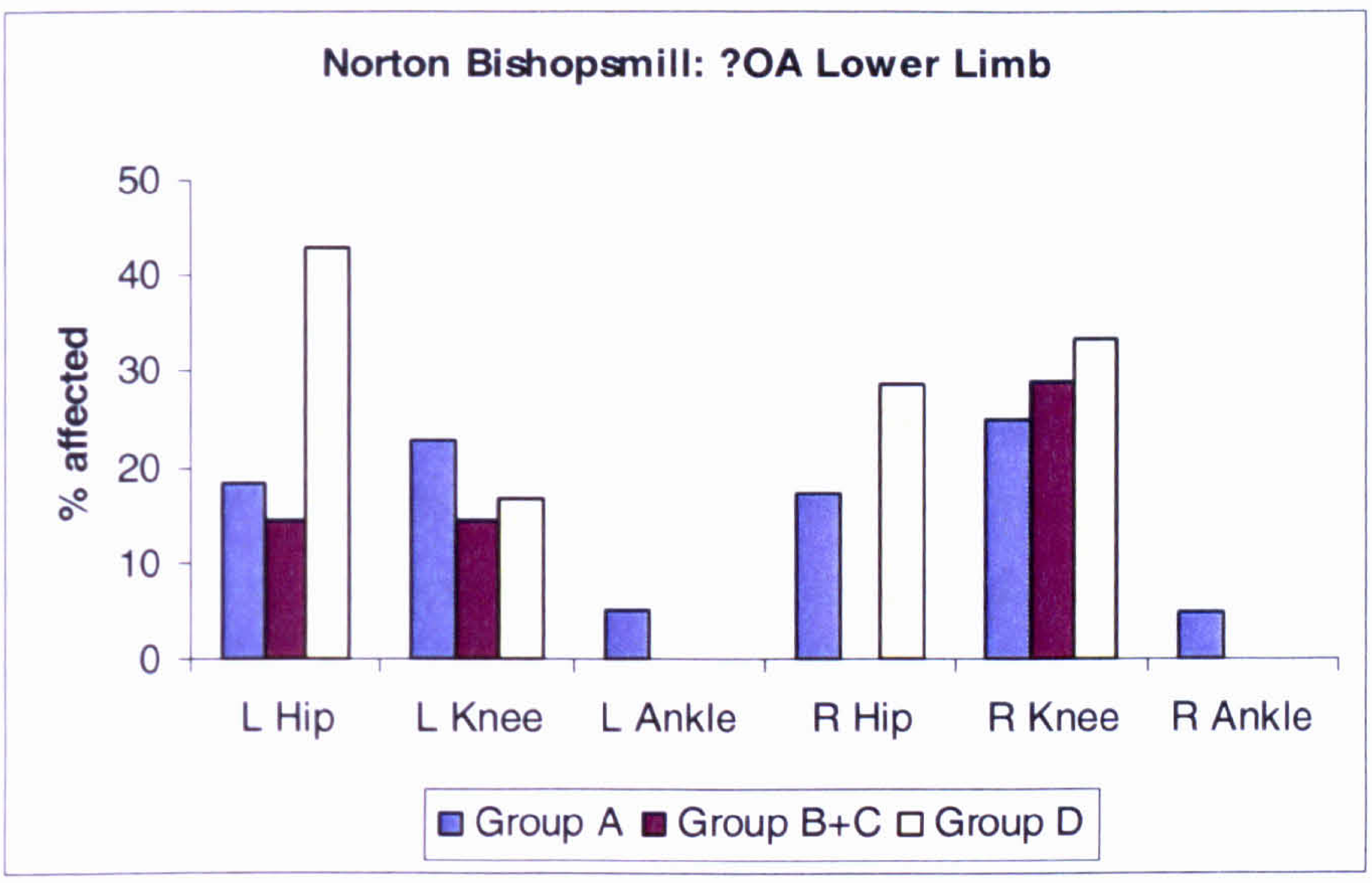


Figure 4.3.4e: The percentage of lower limb joints with possible osteoarthritis from Norton Bishopsmill. .Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

As with the upper limb, the results for OA and ?OA were pooled in order to compare larger samples from the other artefact groups with the individuals from group A. Figure 4.3.4f shows the percentage of joints from the lower limb with osteoarthritis or possible osteoarthritis, from Group A, those with no burial artefacts and from all other individuals from Norton Bishopsmill.

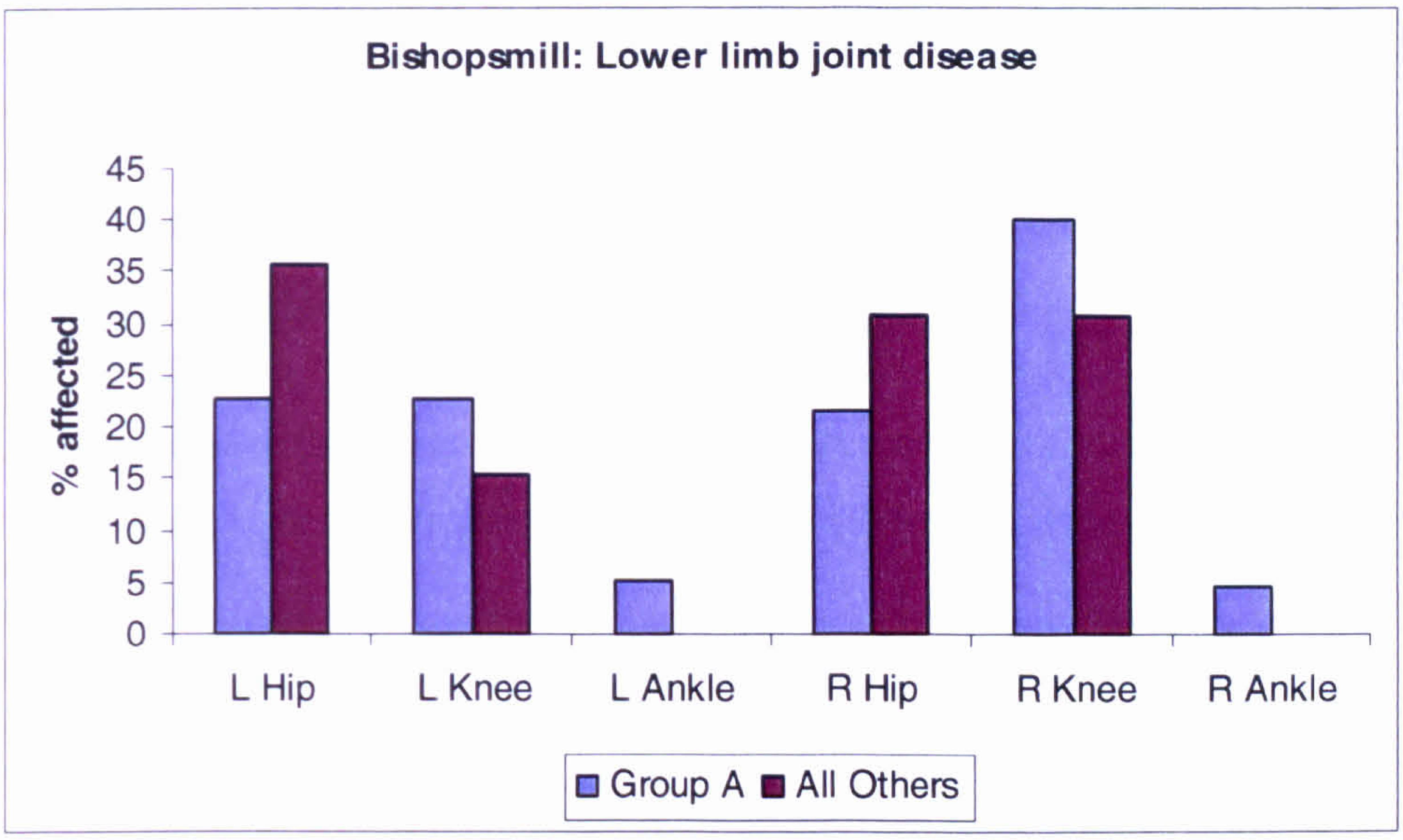


Figure 4.3.4f: The percentage of lower limb joints with osteoarthritis or possible osteoarthritis from Norton Bishopsmill, from Group A and from all other individuals.

This figure shows that, while the percentage of joints affected was higher in Group A for the knees and ankles, the percentage of joints affected was higher in the individuals buried with artefacts in the hip joints. The difference between the percentages of left hip joints affected was on the borderline of statistical significance (chi squared $p = 0.06$, $\alpha = 0.05$), but only the difference between the prevalence of joint disease in the ankle joints was significant (left side $p = 0.02$, right side $p = 0.03$). While these results may suggest a difference between the artefact groups in the risk of joint disease in the lower limb, the small sample size may also have influenced the validity of these results.

Summary: Osteoarthritis

- There were differences in the prevalence of osteoarthritis and possible osteoarthritis between the four sites, with Castledyke South and Bamburgh showing higher frequencies than Norton Mill Lane and Norton Bishopsmill.

- At all four sites there was an increase in the prevalence of osteoarthritis and possible osteoarthritis with increasing age.

- Joints from the right side of the upper limb overall were affected more than the left side, but in the lower limb this pattern was reversed.

- At all four sites there were differences in the percentage of joints affected by changes between the artefact groups, but the differences were most marked in the upper limb.

- At Castledyke South and Norton Mill Lane the males buried with weapons (Group 3) had the most dramatic differences, particularly in the joints from the right side of the upper limb, while the individuals from Group 4 had lower levels of changes than other individuals

- At Bamburgh, Group C males had more joints affected in the left shoulder, left elbow and right wrist than other males, while Group D females had more joints affected in the upper and lower limbs when compared with other females.

- At Norton Bishopsmill Group A individuals had comparatively low levels of changes in both the upper and lower limbs when compared to all other individuals.

4.4: Enthesopathies

In this section the patterns of changes to the entheses in skeletons from each of the four sites are examined to identify any differences in involvement between the artefact groups. The numbers of individuals with entheses present for observation from each site are given in Appendix 3.

4.4.1: Castledyke South

Of the 82 individuals that could be sexed from Castledyke South only one had all 44 entheses present from both sides of the upper limb. Of the individuals examined 77% had possible enthesopathies in the upper limb, and 33% had enthesopathies. Only one individual had all 34 entheses from both sides of the lower limb present for examination. Of the total sample 66% of the individuals examined had possible enthesopathies in the lower limb and 20% had enthesopathies. Tables showing the number of each entheses observed, and the number and percent of entheses with enthesopathies and possible enthesopathies observed for each side of the upper and lower limbs are given in Appendix 3.1.

For all the entheses groups of the upper limb (see Section 3.2.6), the percentage of enthesopathies was greater on the right side, but the laterality of possible enthesopathies was more variable. In all elements from the lower limb, the percentage of enthesopathies was greater on the right side, but the percentage of possible enthesopathies was greater on the left side in all of the entheses except for the entheses of the interosseous membrane between the tibia and fibula. Overall, the percentage of possible enthesopathies was slightly higher on the left side of the lower limb.

Table 4.4.1a shows the number of individuals present of each sex and the average number of entheses present in the upper and lower limbs, and the average number affected by enthesopathies and possible enthesopathies. The number of entheses observed from individuals of each sex is given in brackets.

Sex	No. of Sk	Upper Limb Present	Upper Limb Enth	Upper Limb ?Enth	Lower Limb Present	Lower Limb Enth	Lower Limb ?Enth
Female	43	23 (976)	3 (144)	11 (458)	19 (798)	2 (89)	8 (360)
Male	37	24 (872)	6 (212)	11 (396)	22 (812)	4 (157)	9 (349)

Table 4.4.1a: The number of females and males with entheses present and the average number of entheses present for observation, with enthesopathies and with possible enthesopathies in the upper and lower limbs. The number of entheses is given in brackets.

In both the upper and the lower limbs the average number of enthesopathies was significantly higher in males than in females (single factor ANOVA upper limb p= 0.03, lower limb p= 0.001), but the average number of possible enthesopathies were similar between the sexes.

i) Enthesopathy, Age and Sex

Table 4.4.1b shows the percentage of entheses from both sides of the upper and lower limbs that were observed with enthesopathies, possible enthesopathies, and the percentage of sites that were not affected (None) in females and males from each of the age groups in the skeletal sample from Castledyke South. In the males, the percentage of entheses observed with enthesopathies and possible enthesopathies increased with age, and the percentage of enthesopathies was greater than that seen in females. In both sexes, Chi squared tests showed that the increase in enthesopathies and possible enthesopathies between the age groups for males and females was statistically significant with p values of less than 0.01.

Age Group	Female Enth	Female ?Enth	Female None	Male Enth	Male ?Enth	Male None
Young	6 (24)	28 (105)	66 (252)	14 (63)	31 (139)	55 (245)
Young/ Middle	12 (41)	51 (180)	37 (129)	22 (47)	45 (95)	32 (68)
Middle	18 (64)	48 (170)	34 (118)	26 (103)	50 (198)	24 (97)
Older	16 (94)	52 (311)	32 (190)	26 (154)	51 (302)	23 (136)
Adult	10 (10)	54 (52)	35 (34)	5 (2)	30 (11)	65 (24)

Table 4.4.1b: The percentage and number (in brackets) of entheses from both sides of the upper and lower limbs, in each age group that showed enthesopathies (Enth), possible enthesopathies (?Enth), and no changes in females and males from Castledyke South. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely

ii) Enthesopathy and Status

Tables showing the number and the percentage of enthesis groups from the left and right sides of the upper land lower limbs that were affected with enthesopathies and possible enthesopathies, and the number and percentage of individuals affected from each of the burial artefact groups in the skeletal sample from Castledyke South are given in Appendix 3.1. While there were clear differences between the percentages of enthesopathies between the artefact groups, the percentages of entheses with possible enthesopathies were similar between the four artefact groups. The percentage of individuals with entheses affected was similar for all four of the artefact groups, but Group 3 had the lowest percentage of individuals affected by enthesopathies, but all individuals in this group had possible enthesopathies.

These results suggest that at Castledyke South at least, the changes to the entheses identified as possible enthesopathies may just be part of normal skeletal variation. Therefore for this sample possible enthesopathies will not be examined further, but as the results for osteoarthritis have shown, there is a great deal of variation of expression of skeletal changes between the four sites, so at the other sites, both grades of changes to the entheses will still be explored.

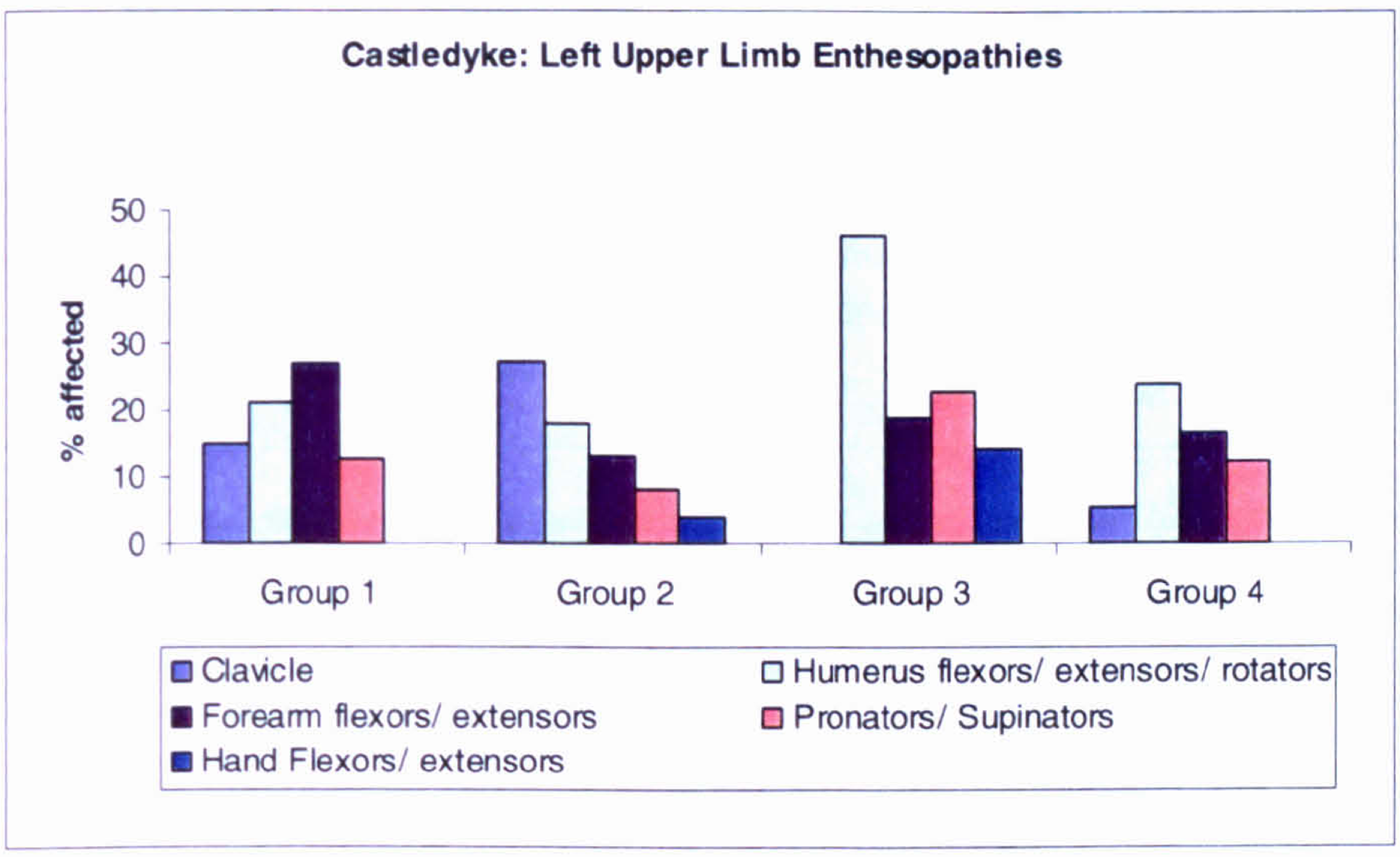


Figure 4.4.1a: The percentage of enthesopathies in the left side of the upper limb each of the artefact groups from Castledyke South. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.4.1a shows the percentage of entheses from the left side of the upper limb in each of the artefact groups that showed enthesopathies. The pattern of entheses affected in Group 3 males, those buried with weapons, was very different to the pattern seen in the other groups, particularly in the humeral flexor entheses, while none of the left clavicle entheses were affected in this group. Figure 4.4.1b shows the percentage of enthesopathies from the right side of the upper limb in each of the artefact groups. The majority of the entheses showed higher percentages of changes on the right side than on the left. As in the left side, Group 3 had high levels of changes, except for the clavicle where there were no entheses affected. Group 1 also had high levels of changes in the right side of the upper limb, except in the flexors and extensors of the hand. All four groups had higher percentages of entheses affected on the right side of the upper limb.

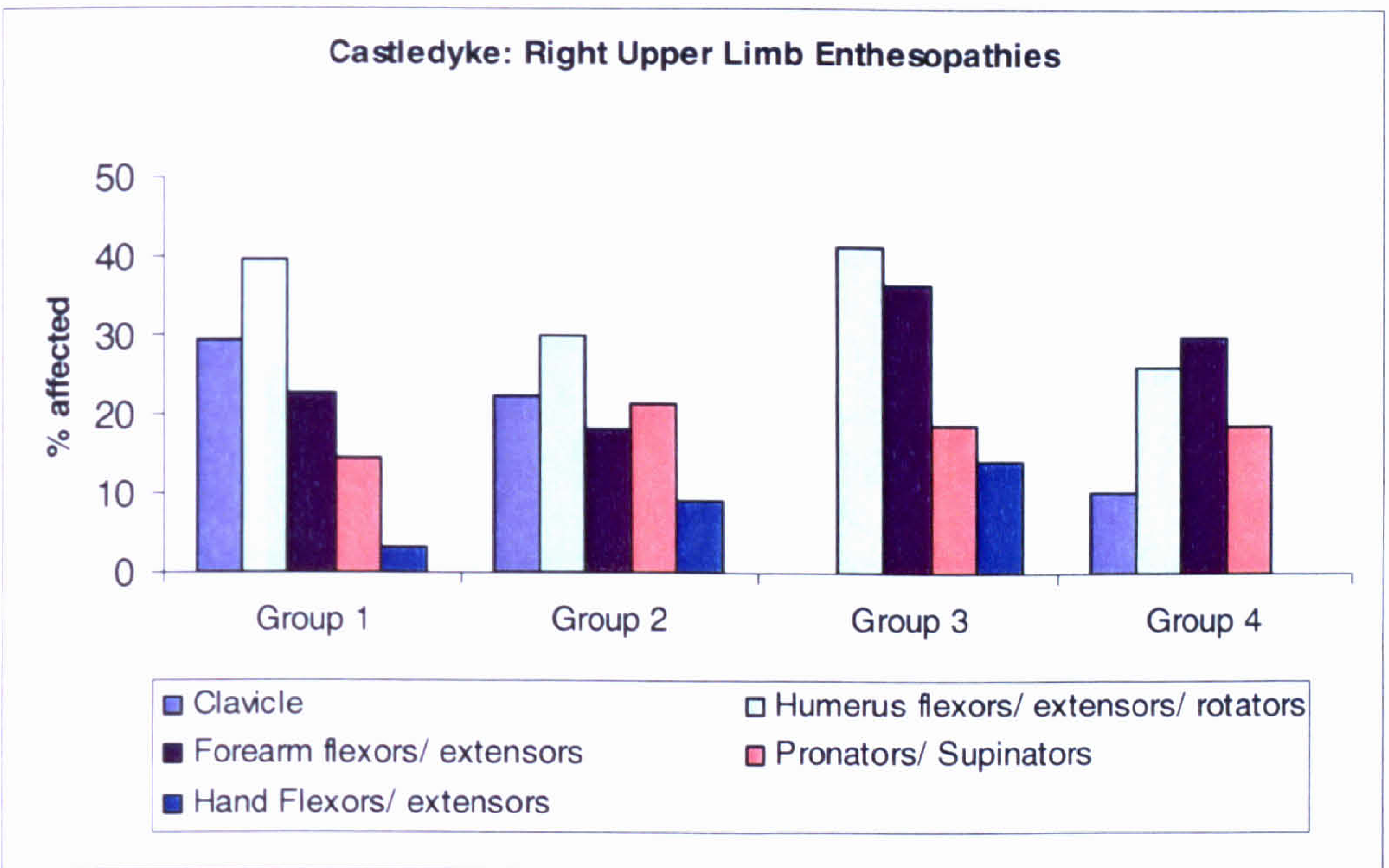


Figure 4.4.1b: The percentage of enthesopathies in the right side of the upper limb each of the artefact groups from Castledyke South. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

In order to examine whether the differences in sex between the groups were primarily the cause of the differences observed in patterns of enthesopathies, the results from Group 3 were compared with all other males and Group 4 was compared with all other females. Figures 4.4.1c and 4.4.1d show the percentage of entheses affected in the left and right sides of the upper limb in Group 3 males and all other males from Castledyke South.

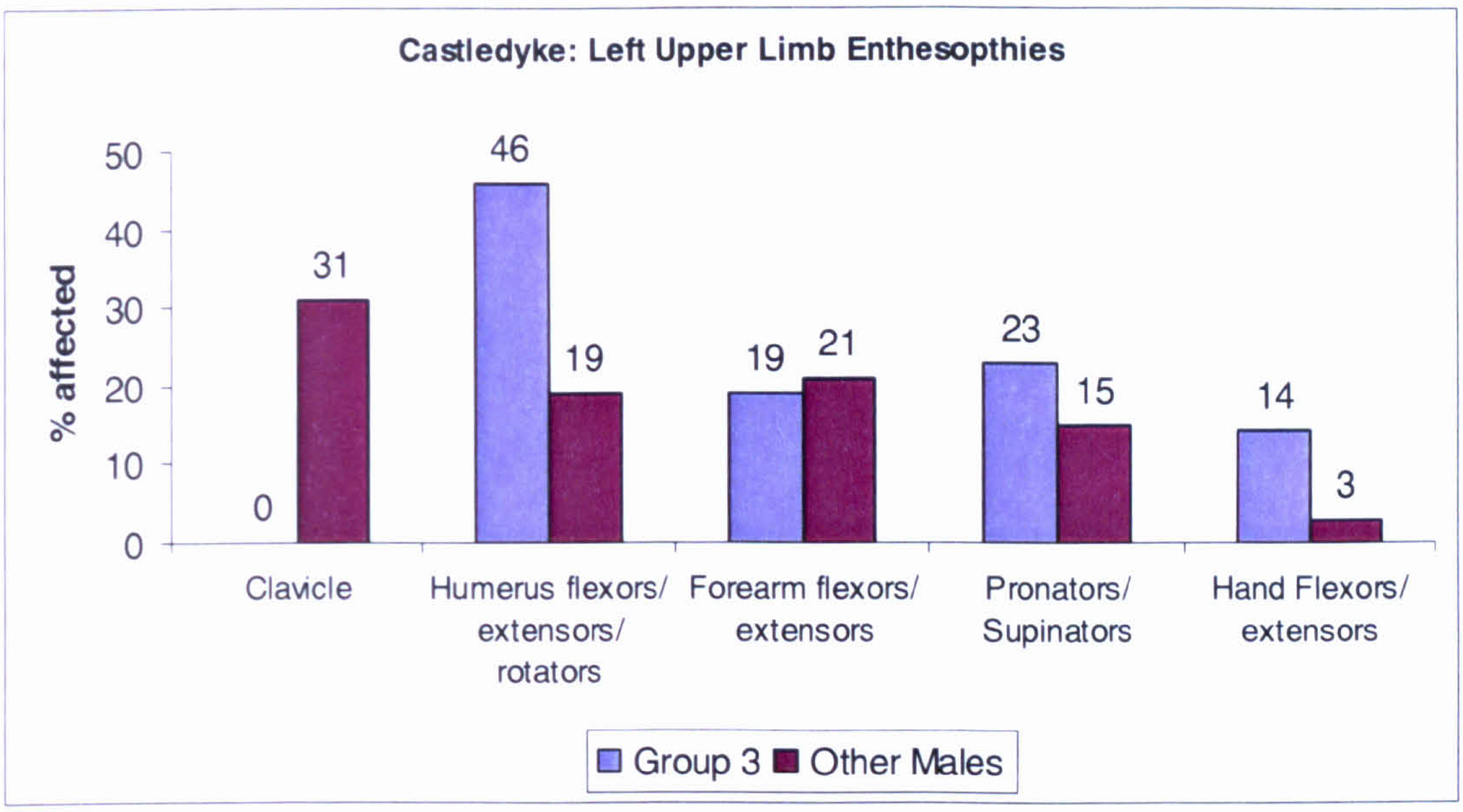


Figure 4.4.1c: The percentage of enthesopathies in the left upper limb from Group 3 and all other males.

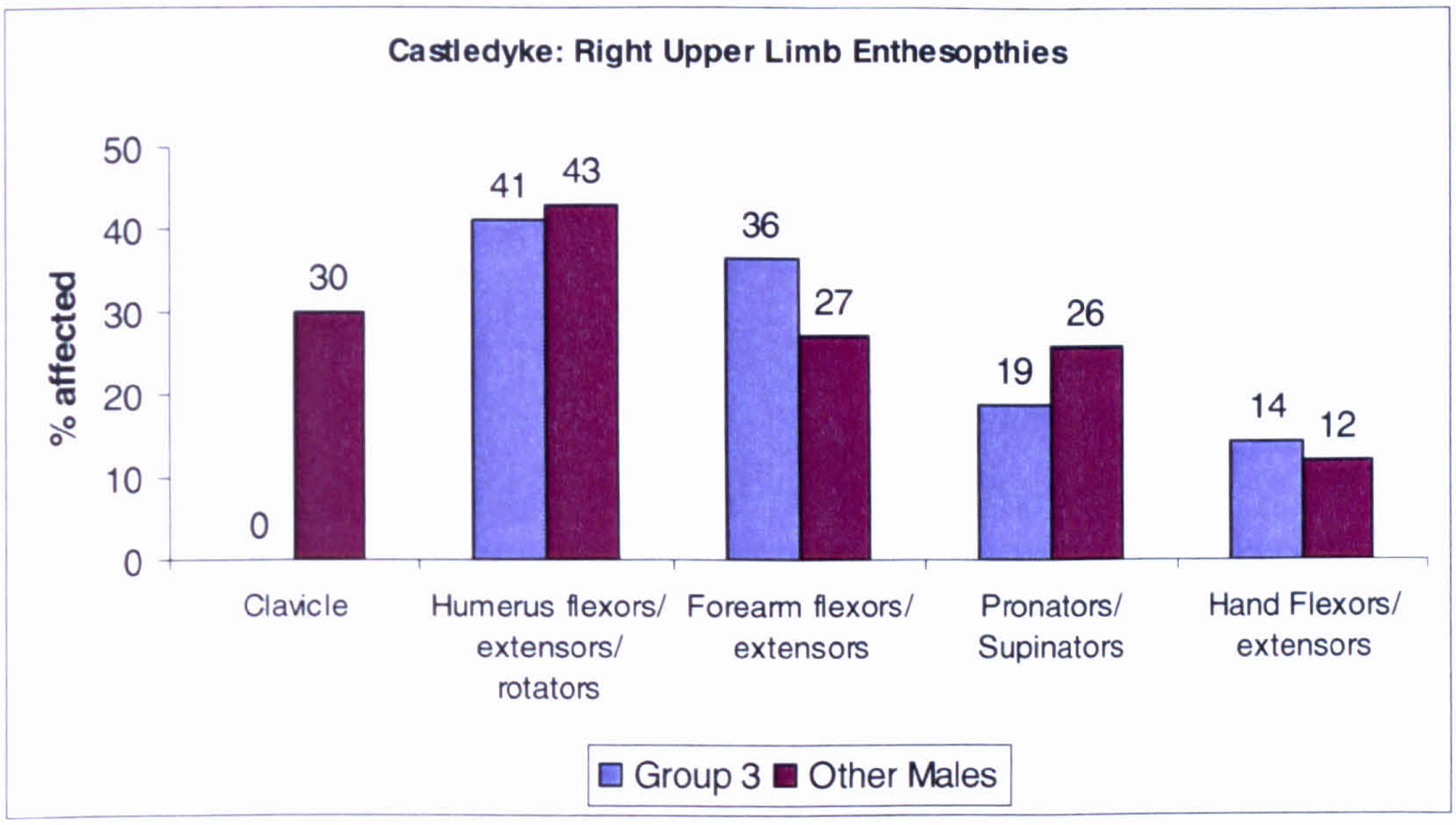


Figure 4.4.1d: The percentage of enthesopathies in the right upper limb from Group 3 and all other males.

In Group 3 the percentage of left humeral flexors and extensors with enthesopathies was significantly higher than that seen in all other males (chi squared p = 0.04), but on the right side the percentages of affected entheses were more similar between the two groups. The fact that none of the entheses from the clavicle were affected in Group 4 was also striking, particularly as the percentage of enthesopathies in this element was comparatively high in all other males. Figures 4.4.1e and 4.4.1f show the percentage of entheses affected from the left and right sides of the upper limb in Group 4 and females from all other artefact groups.

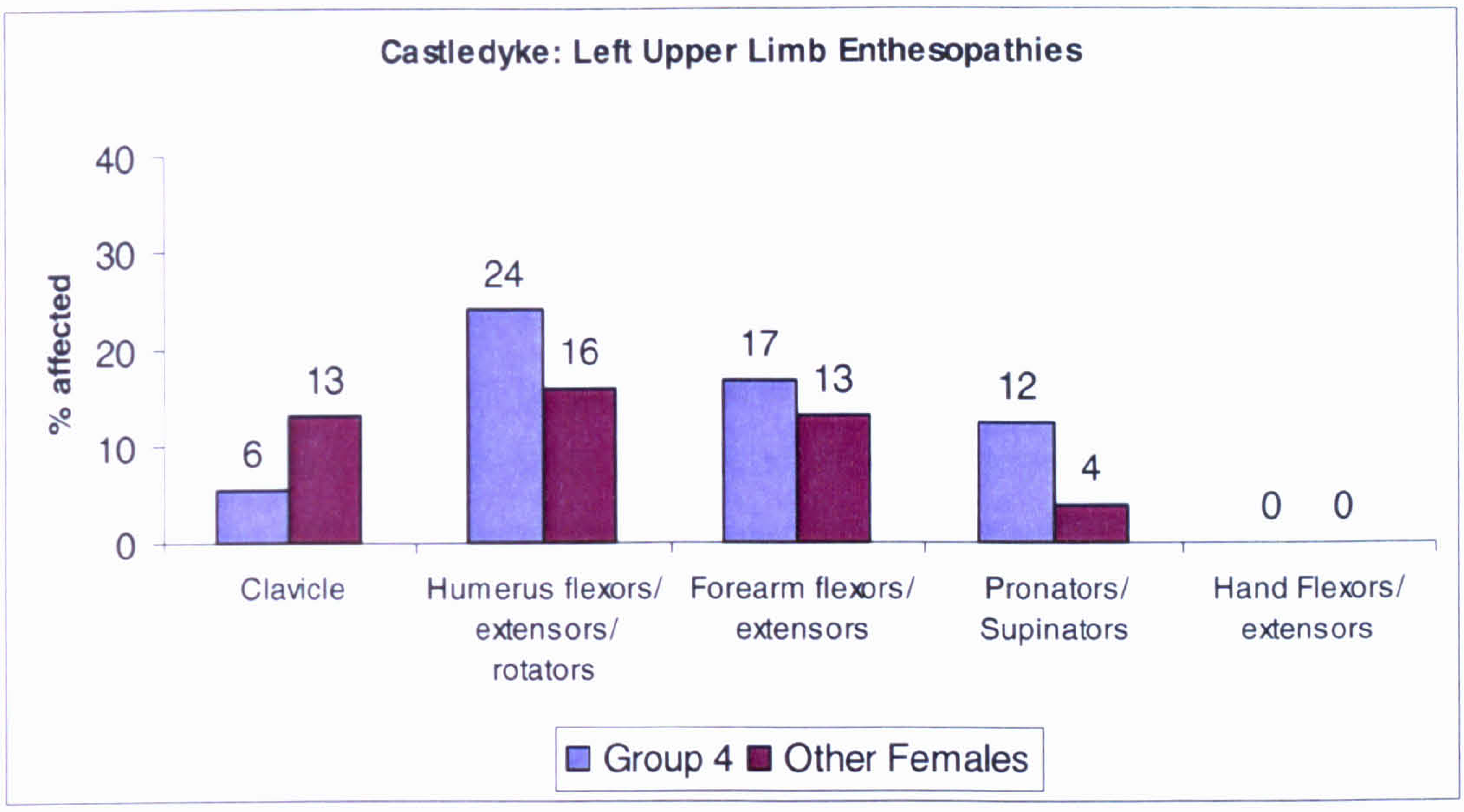


Figure 4.4.1e: The percentage of entheses affected in the left upper limb from Group 4 and all other females.

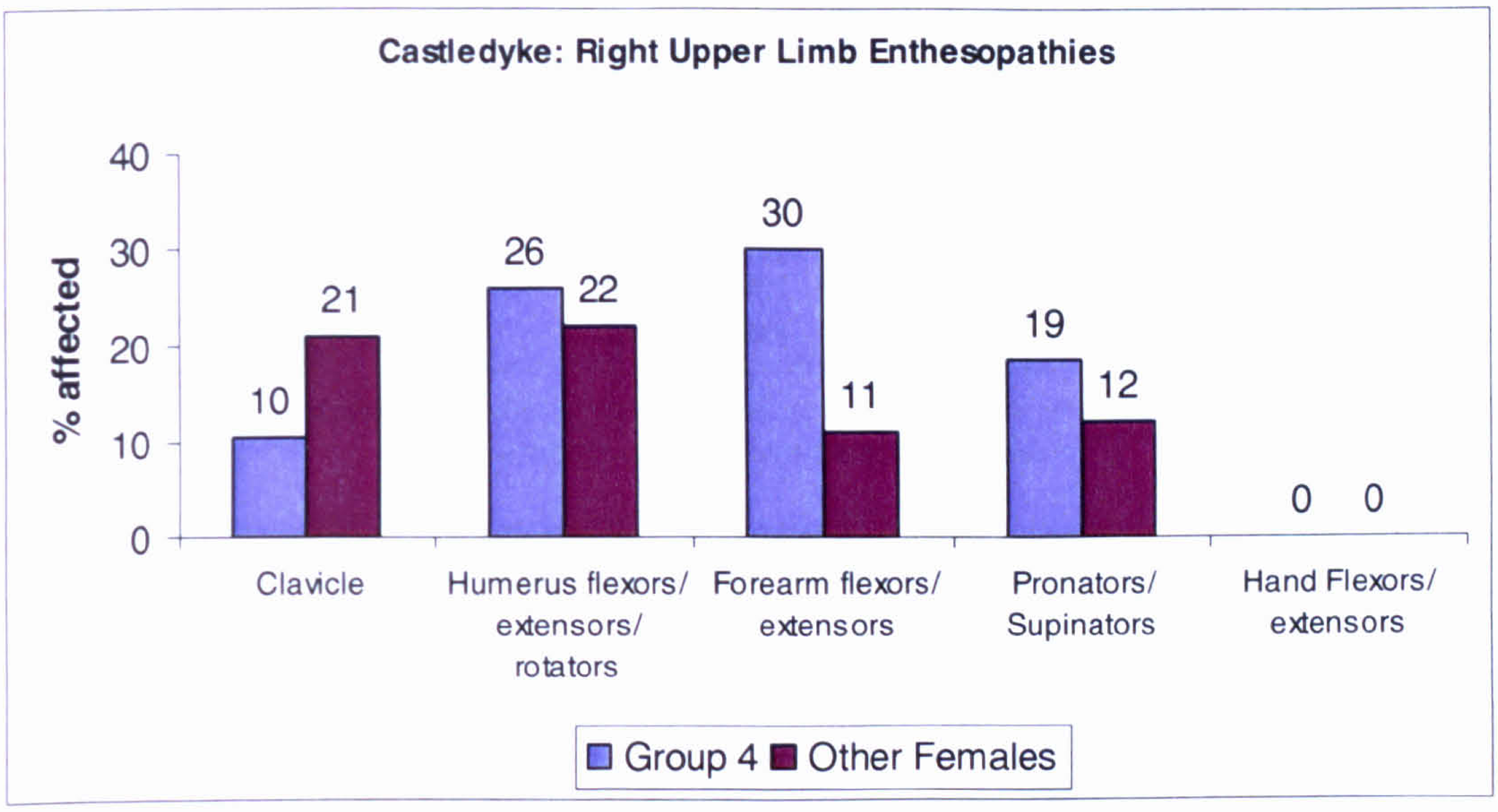


Figure 4.4.1f: The percentage of entheses affected in the right upper limb from Group 4 and all other females.

With the exception of the entheses of the clavicle, Group 4 females had higher percentages of changes than all other females from Castledyke South, in both the left and right sides of the upper limb. In particular, the percentage of right forearm flexors and extensors affected was much higher in Group 4 females.

In the lower limb the percentage of entheses affected was higher on the right side for all entheses in Group 1 and Group 2, but in Groups 3 and 4 the percentage of enthesopathies from the left side was higher in the gluteus and adductor and the foot flexor entheses. The percentages of possible enthesopathies were higher than the percentage of enthesopathies in all groups, and tended to be higher on the left side than on the right in Group 1, Group 2 and Group 3. However in Group 4 the percentage of gluteus and adductor, quadriceps and foot flexor entheses affected was higher on the left side than on the right.

Figure 4.4.1g and 4.4.1h shows the percentage of entheses with enthesopathies from the left and right sides of the lower limb from each of the artefact groups at Castledyke South.

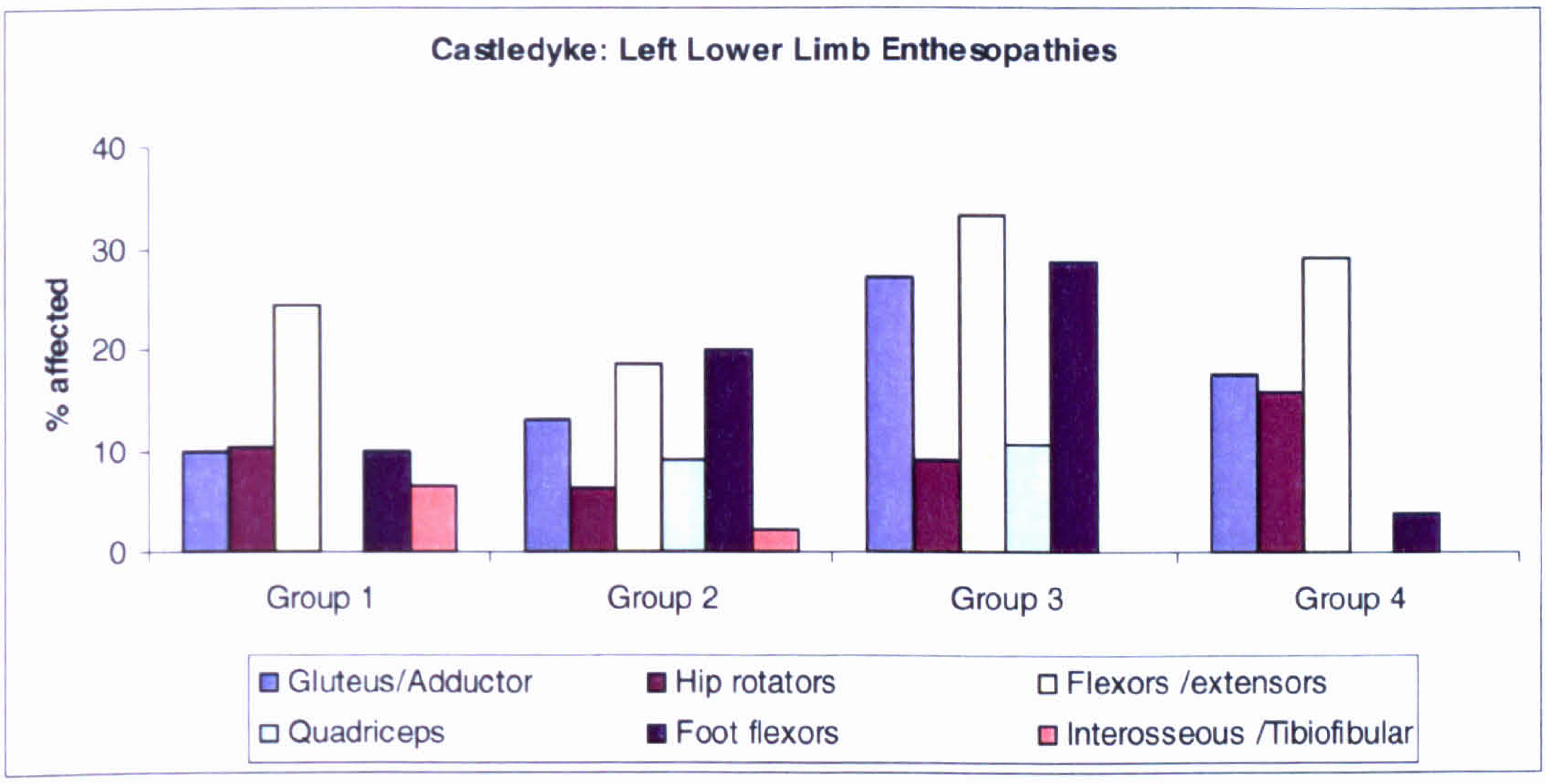


Figure 4.4.1g: The percentage of entheses from the left side of the lower limb with enthesopathies in each of the artefact groups from Castledyke South.

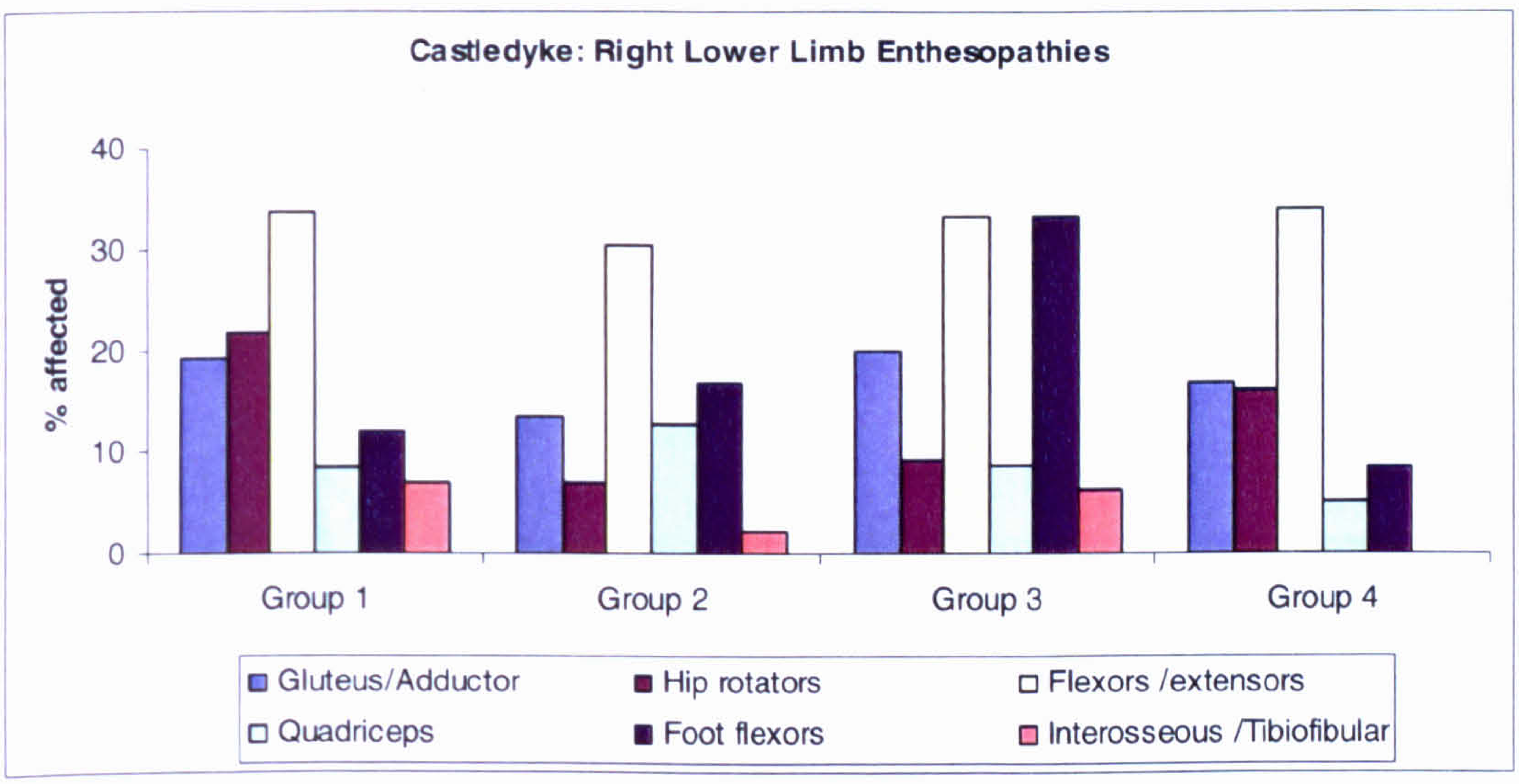


Figure 4.4.1h: The percentage of entheses from the right side of the lower limb with enthesopathies in each of the artefact groups from Castledyke South.

These figures show that in the left side of the lower limb, Group 3 had a higher percentage of changes in the gluteus and adductor, femoral flexors and extensors, quadriceps and foot flexors than the other artefact groups. In the right side, Group 3 had high levels of changes in the foot flexors, femoral flexors and extensors and the gluteus and adductor, but Group 1 had the highest levels of changes in the hip rotators. Figure 4.4.1i shows the percentage of entheses with changes from the left lower limb from Group 3, compared with all other males, while Figure 4.4.1j shows the percentage of entheses from the right side of the lower limb.

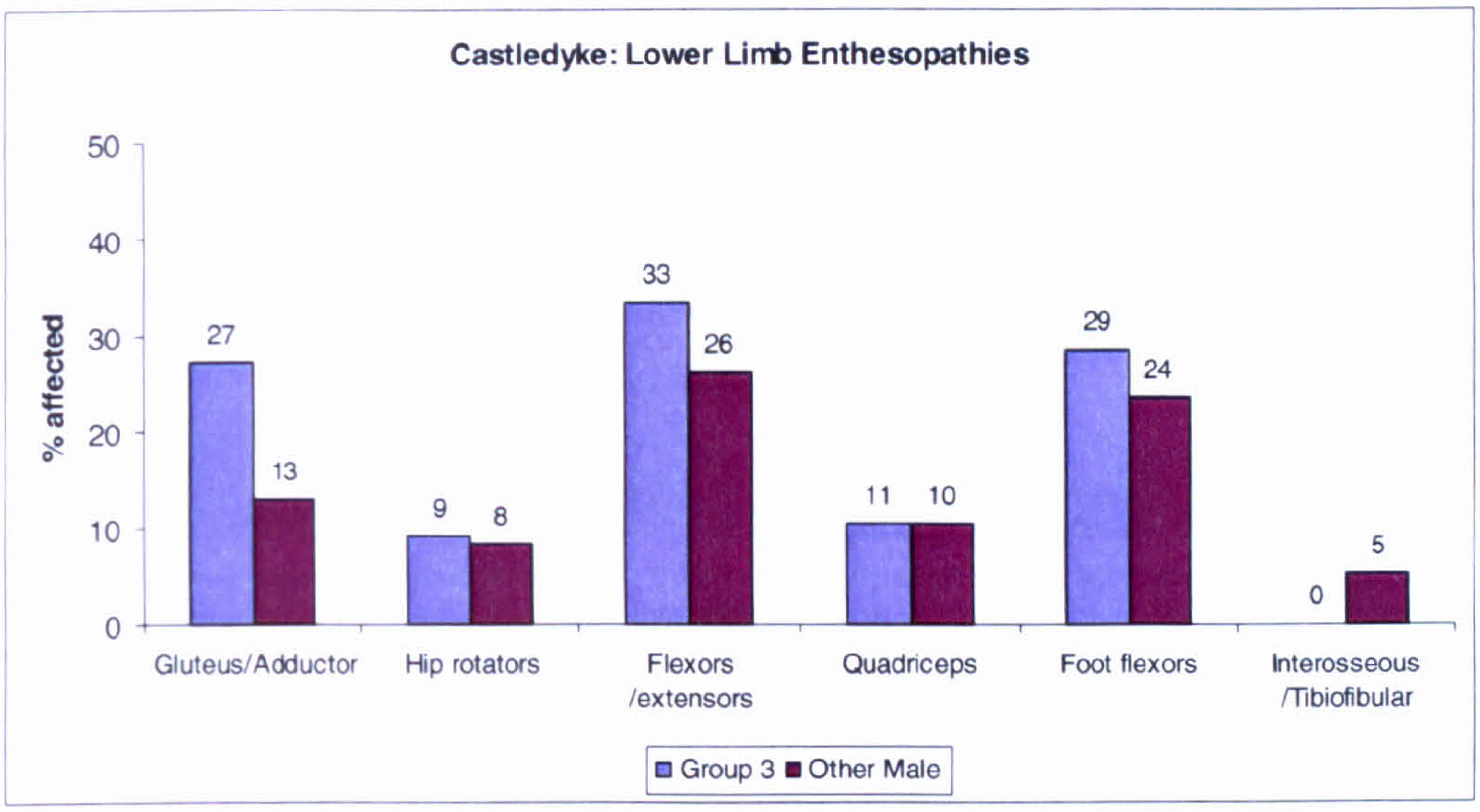


Figure 4.4.1i: the percentage of changes to the entheses from the left side of the lower limb from Group 3 and all other males from Castledyke.

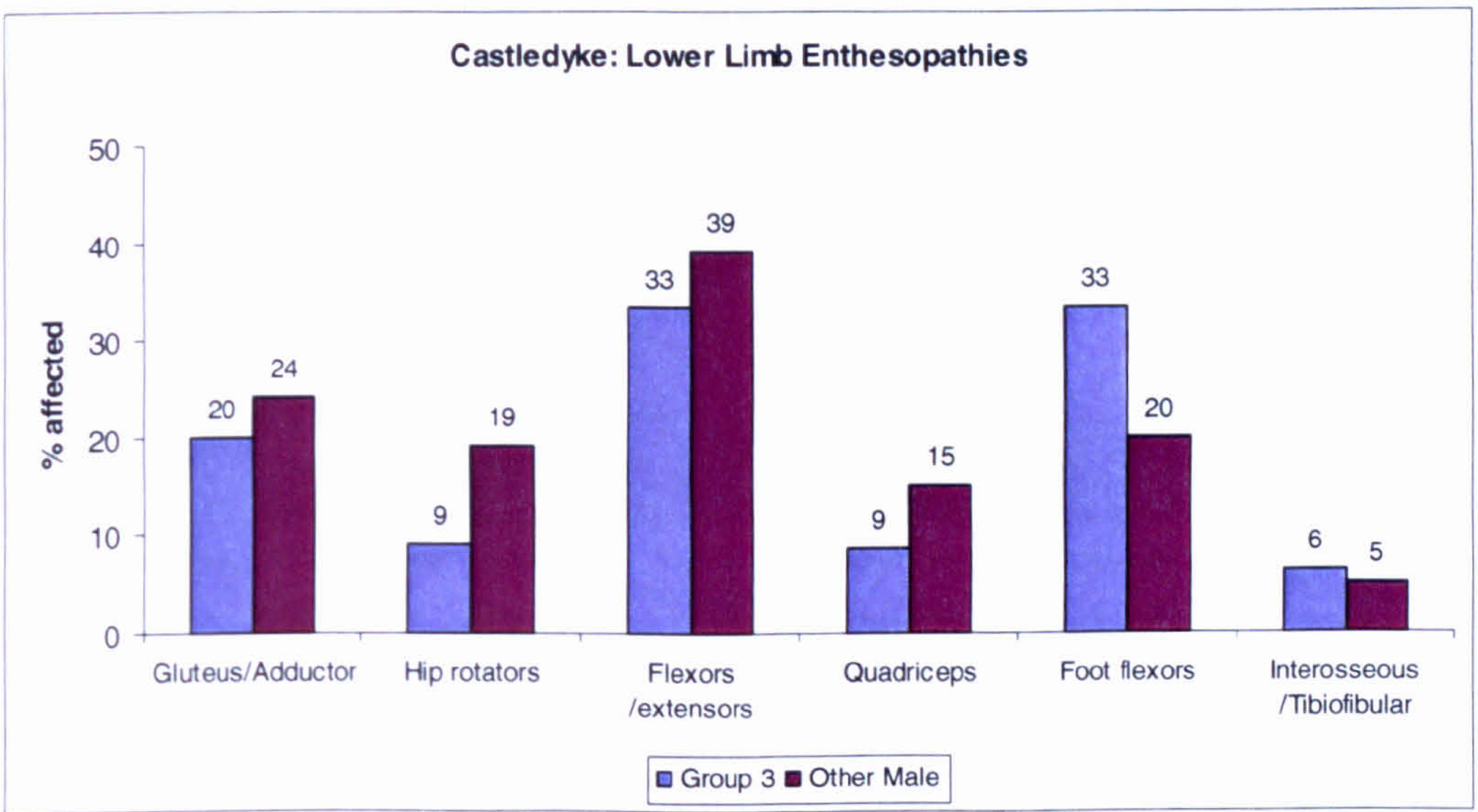


Figure 4.4.1j: the percentage of changes to the entheses from the right side of the lower limb from Group 3 and all other males from Castledyke.

In the left lower limb, Group 3 males had a higher percentage of changes in all entheses, except the interosseous of the tibia and fibula. On the right side all other males had higher levels of changes except in the foot flexors and interosseous. Figures 4.4.1k and 4.4.1l show the percentage of entheses affected in the left and right sides of the lower limb in Group 4 and all other females from Castledyke.

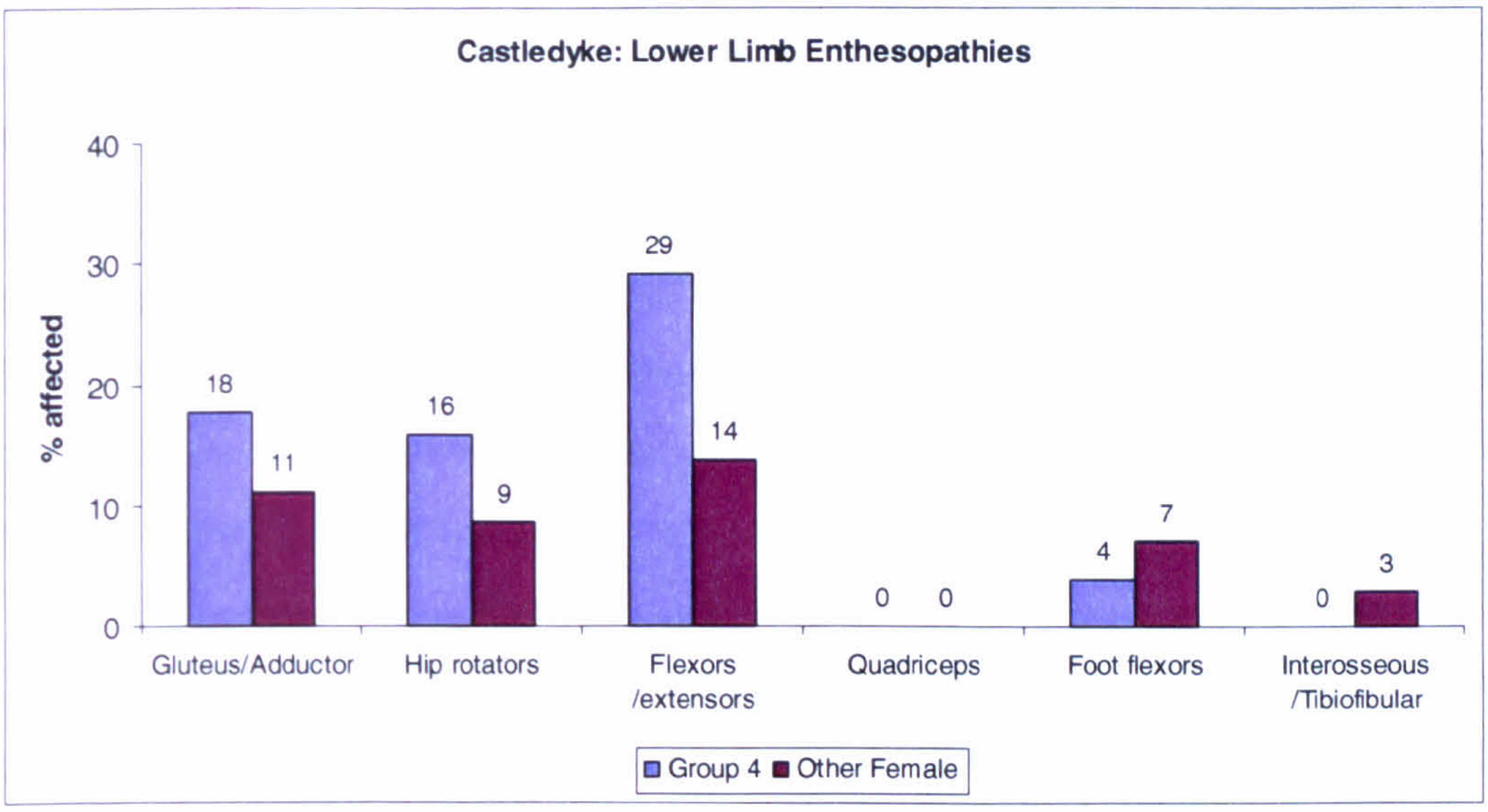


Figure 4.4.1k: The percentage of changes to the entheses in the left side of the lower limb from Group 4 and all other females from Castledyke

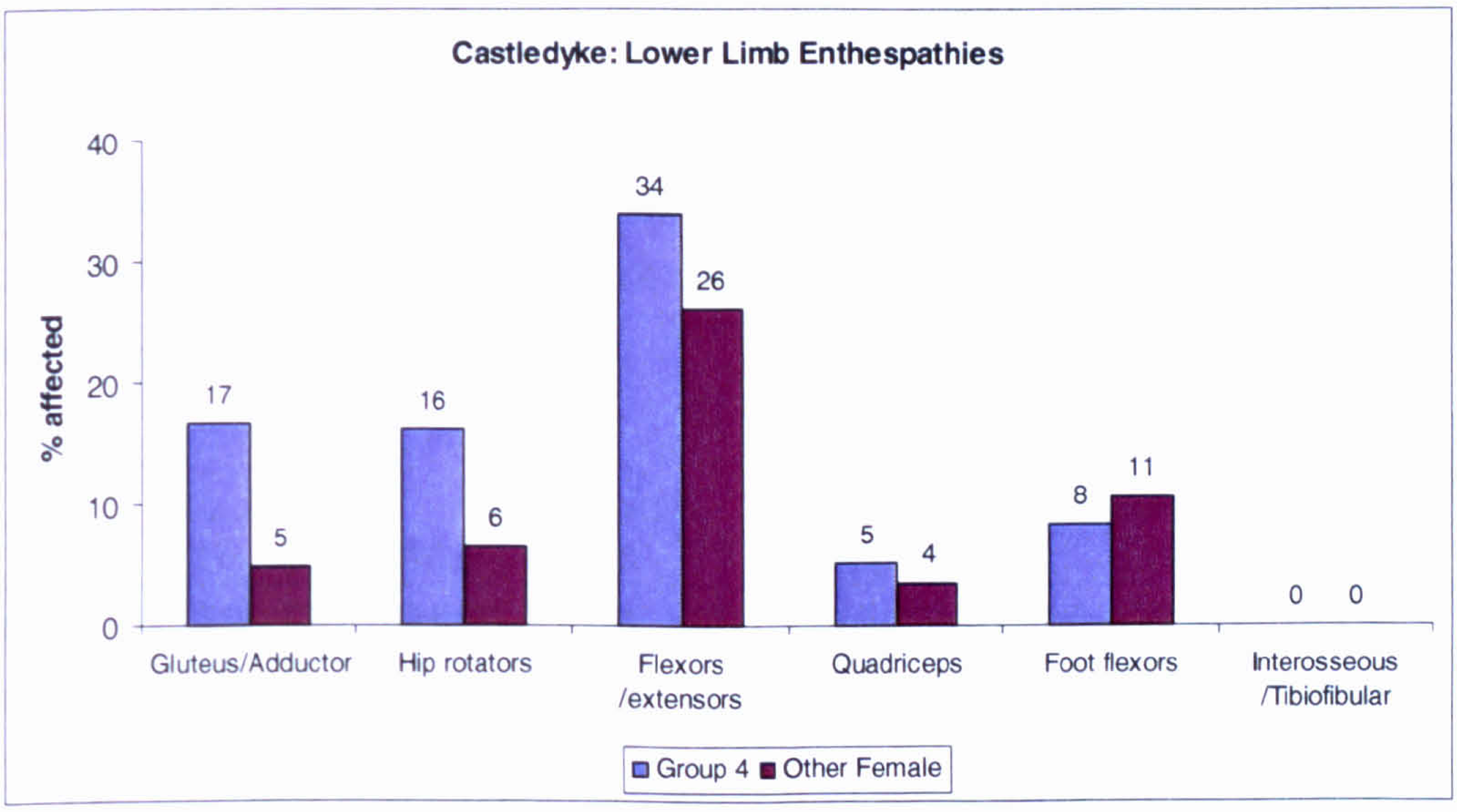


Figure 4.4.1l: The percentage of changes to the entheses in the right side of the lower limb from Group 4 and all other females from Castledyke

As with the results for the upper limb, in both sides of the lower limb Group 4 had a higher prevalence of changes in the gluteus and adductor, hip rotators and femur flexors and extensors than all other females. However the percentage of foot flexor entheses affected was higher in all other females. These differences suggest that there may have been a factor or factors that led to Group 4 females being more likely to develop enthesopathies than other females at Castledyke.

4.4.2: Norton Mill Lane

Of the 48 individuals from Norton Mill Lane that could be sexed, only one individual had all 78 entheses present; 19% of the individuals had enthesopathies and 48% had possible enthesopathies in the upper limb. Two percent of the individuals examined had enthesopathies in the lower limb, and 42% had possible enthesopathies. Tables showing the number of each entheses observed, and the number and percent of entheses with enthesopathies and possible enthesopathies observed for each side of the upper and lower limbs are given in Appendix 3.2.

The percentage of enthesopathies was higher on the right side of the upper limb, for all of the groups of entheses, but the percentage of possible enthesopathies was higher on the left side for the clavicle and forearm flexors and extensors. The percentage of entheses with enthesopathies was highest on the right side of the lower limb but, as with the upper limb, the laterality of possible enthesopathies was more varied and generally higher on the left side. Table 4.4.2a shows the number of individuals present of each sex and the average number of entheses present in the upper and lower limbs, and the average number affected by enthesopathies and possible enthesopathies. The number of entheses from each sex is given in brackets.

Sex	No. of Sk	Upper Limb Present	Upper Limb Enth	Upper Limb ?Enth	Lower Limb Present	Lower Limb Enth	Lower Limb ?Enth
Female	19	32 (475)	3 (39)	8 (116)	25 (470)	1 (19)	5 (94)
Male	27	30 (753)	3 (81)	6 (158)	27 (718)	2 (44)	6 (157)

Table 4.4.2a: The number of females and males with entheses present and the average number of entheses present, with enthesopathies and with possible enthesopathies in the upper and lower limbs. The number of entheses present is given in brackets.

In contrast to the results from Castledyke South, at Norton Mill Lane there was no significant difference in the average number of enthesopathies or possible enthesopathies observed in males and females (single factor ANOVA upper limb p= 0.4, lower limb p=

0.2). In the upper limb the average number of possible enthesopathies was higher in females than in males, but in the lower limb the average number of changes was slightly higher in males.

i) Enthesopathy, Age and Sex

Table 4.4.2b shows the percentage of entheses from both sides of the upper and lower limbs that were observed with enthesopathies, possible enthesopathies, and the percentage of entheses that were not affected (None) in females and males from each of the age groups in the skeletal sample from Norton Mill Lane. In females there was an increase in enthesopathies with age, but the possible enthesopathies tended to decrease with age. In males the pattern was reversed with possible enthesopathies increasing with age and enthesopathies being more even across the age groups.

Age Group	Female			Male		
	Enth	?Enth	None	Enth	?Enth	None
Young	6 (17)	19 (50)	75 (202)	9 (37)	13 (58)	78 (340)
Young/ Middle	4 (15)	29 (103)	67 (234)	6 (16)	17 (48)	77 (211)
Middle	6 (13)	21 (46)	73 (164)	11 (55)	27 (142)	62 (323)
Older	13 (11)	13 (11)	74 (61)	6 (13)	30 (66)	64 (143)
Adult	11 (2)	17 (3)	72 (13)	13 (6)	23 (11)	64 (30)

Table 4.4.2b: The percentage and number in brackets, of entheses from both sides of the upper and lower limbs in each age group that showed enthesopathies, possible enthesopathies, and no changes in females and males from Norton Mill Lane. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely

While young individuals had the lowest levels of possible enthesopathies, the pattern was not as clear-cut as that seen at Castledyke South. The variation seen in possible enthesopathies in both males and females was statistically significant (chi squared p=0.01). However, the results for enthesopathies were a little different; in females the variation in enthesopathies with age was not statistically significant (p=0.7), but in males these results were statistically significant (p=0.01). Consequently it is likely that in males, the differences in enthesopathies and possible enthesopathies were the result of increasing age, rather than another factor, but in females the association might be more complex.

ii) Enthesopathy and Status

Tables showing the number and the percentage of enthesis groups from the left and right sides of the upper land lower limbs that were affected with enthesopathies and possible enthesopathies, and the number and percentage of individuals affected from each of the burial artefact groups in the skeletal sample from Norton Mill Lane are given in Appendix 3.2. Group 3, the males buried with weapons, had the highest percentage of individuals with enthesopathies and possible enthesopathies. Overall, the percentages of entheses with changes were lower than those seen at Castledyke South; none of the artefact groups had individuals with enthesopathies in the entheses of the hand flexors and extensors (the oblique line and dorsal tubercle of the radius), and there were few possible enthesopathies in this region. The highest percentages of enthesopathies were seen in the right forearm flexors and extensors in Groups 1 and 2, the individuals with few or no burial artefacts. Generally the percentage of possible enthesopathies was lower in Group 4 than in the other artefact groups, with the exception of the right humeral flexors and the right forearm flexors and extensors, although the percentage of individuals affected was relatively high.

Figures 4.4.2a and 4.4.2b show the percentage of enthesopathies from the left and right sides of the upper limb in each of the artefact groups. As the patterns of possible enthesopathies were much more homologous than the pattern of enthesopathies, and hence more likely to be a part of normal variation, only enthesopathies are used for the examination of the differences between artefact groups.

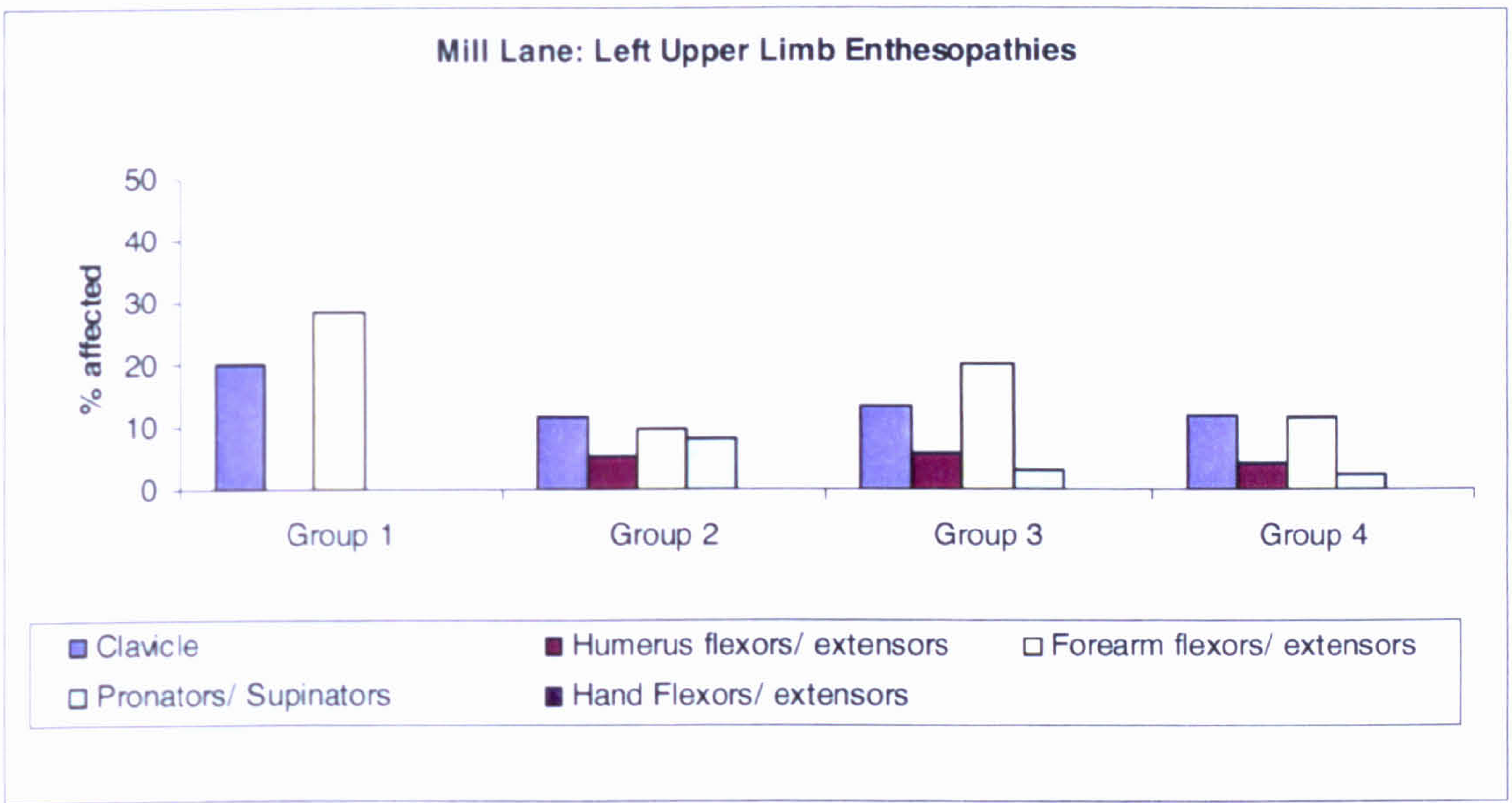


Figure 4.4.2a: The percentages of enthesopathies in the left side of the upper limb each of the artefact groups from Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

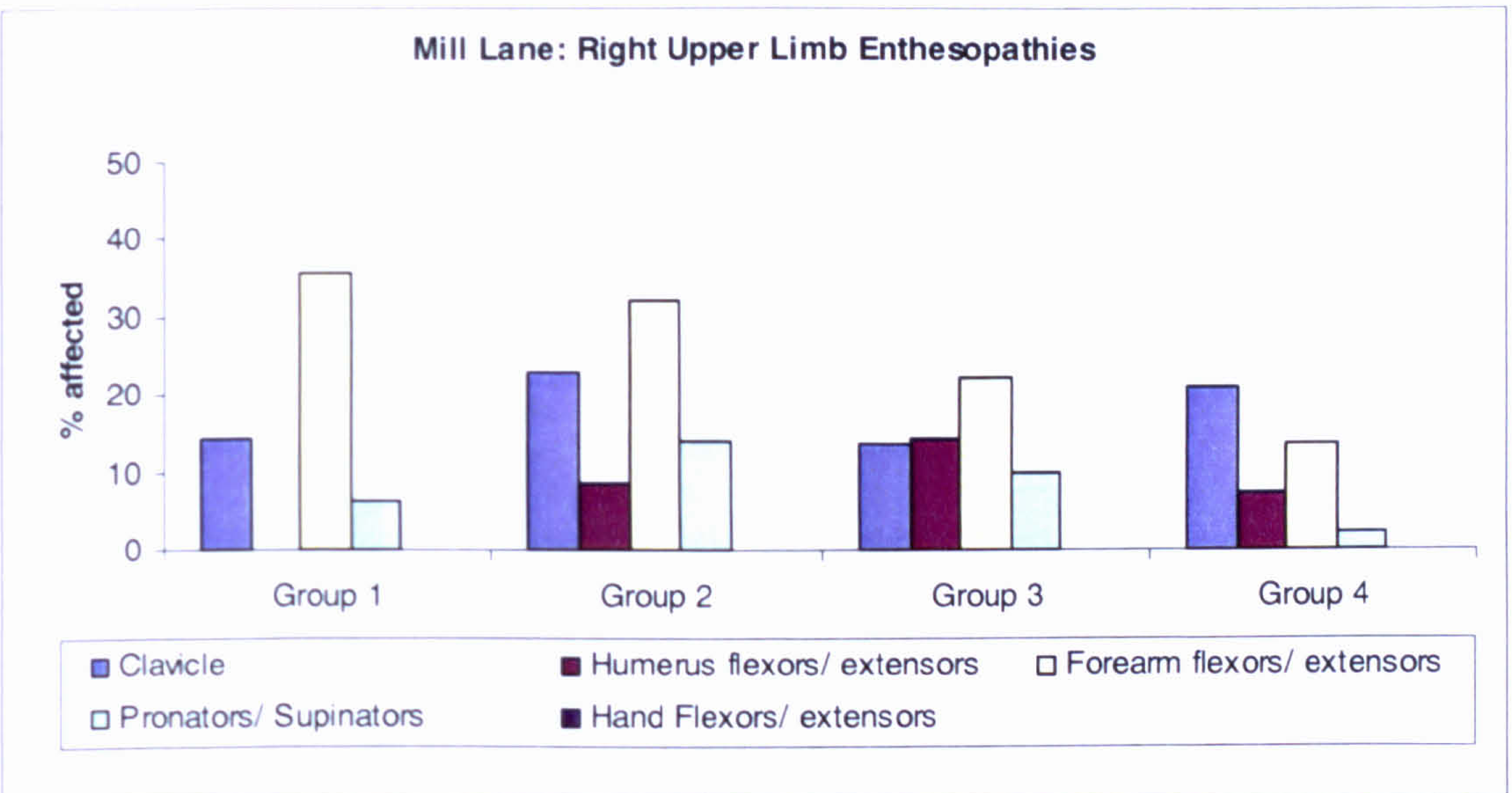


Figure 4.4.2b: The percentages of enthesopathies in the right side of the upper limb in each of the artefact groups from Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Group 1 had a high percentage of changes to the forearm flexor and extensor entheses on both sides, but no changes to the humeral flexors and extensors or the pronators and supinators on the left side. Groups 3 and 4 had similar patterns of changes, except that the percentage of enthesopathies in the clavicle was higher in the right side of Group 4 than in

Group 3. Figures 4.4.2c and 4.4.2d show the percentage of entheses affected in the left and right sides of the upper limb in Group 3 males and all other males from Norton Mill Lane.

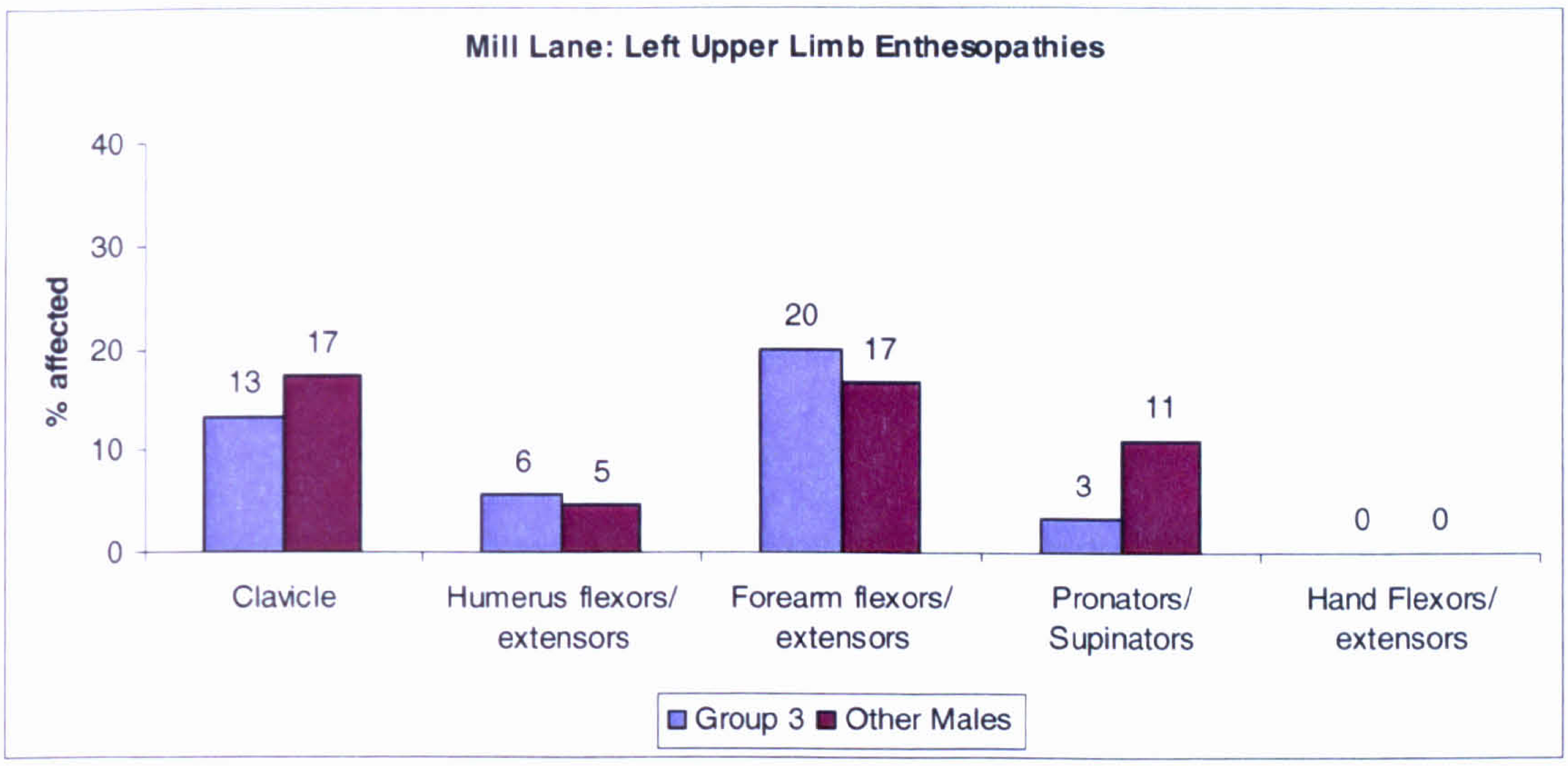


Figure 4.4.2c: The percentage of entheses affected in the left upper limb from Group 3 and all other males.

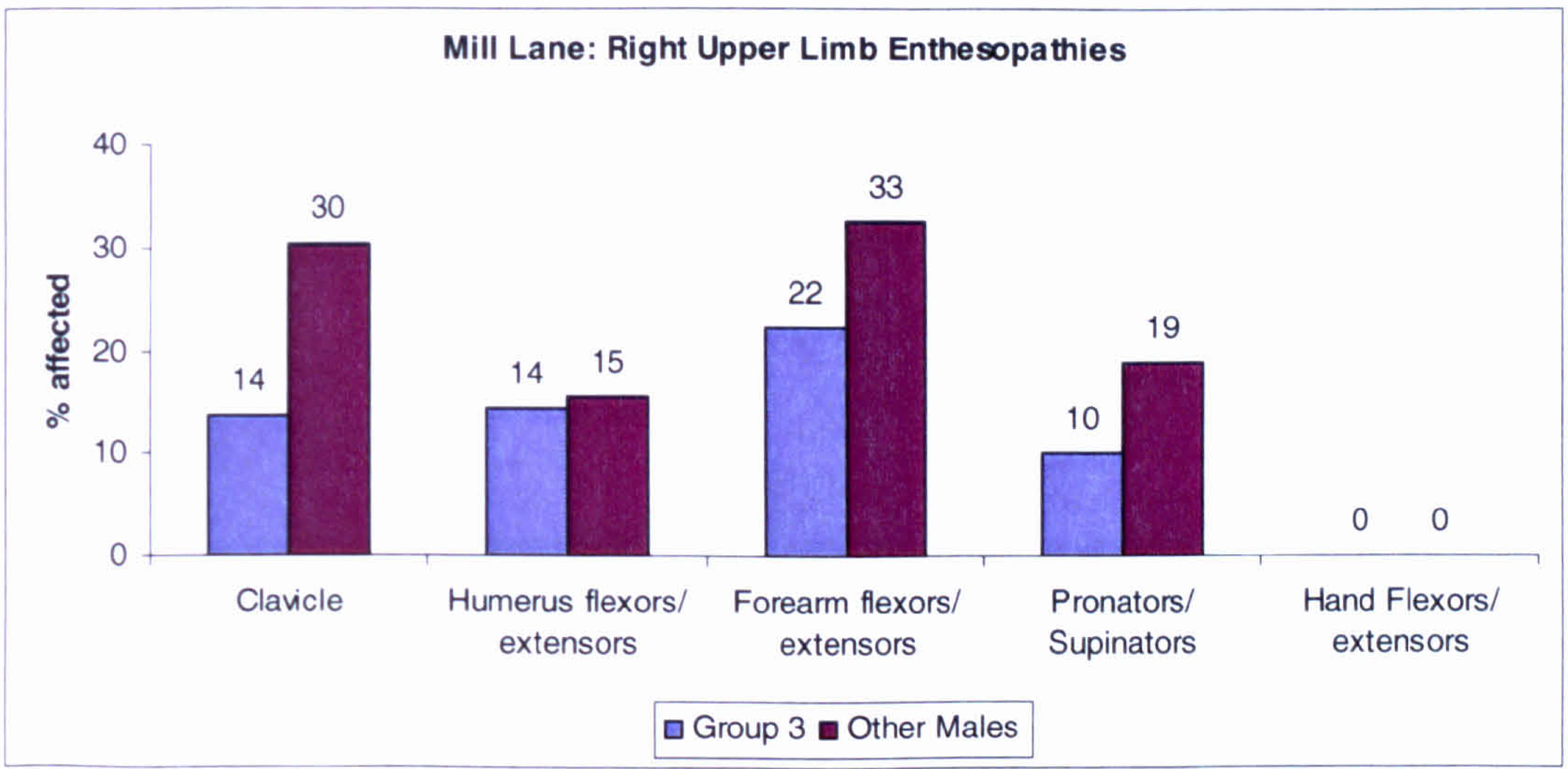


Figure 4.4.2d: The percentage of entheses affected in the right upper limb from Group 3 and all other males.

These figures show that, while the percentage of entheses affected in Group 3 was higher in left the forearm flexors and marginally higher in the left humeral flexors and extensors, in all other entheses on the left and right sides all other males had higher prevalences of changes. Figures 4.4.2e and 4.4.2f show the percentage of entheses affected from the left and right sides of the upper limb in Group 4 and individuals from all other artefact groups.

Other than in the right clavicle, Group 4 individuals had lower percentages of entheses affected, particularly in the right forearm flexors and the pronators and supinators.

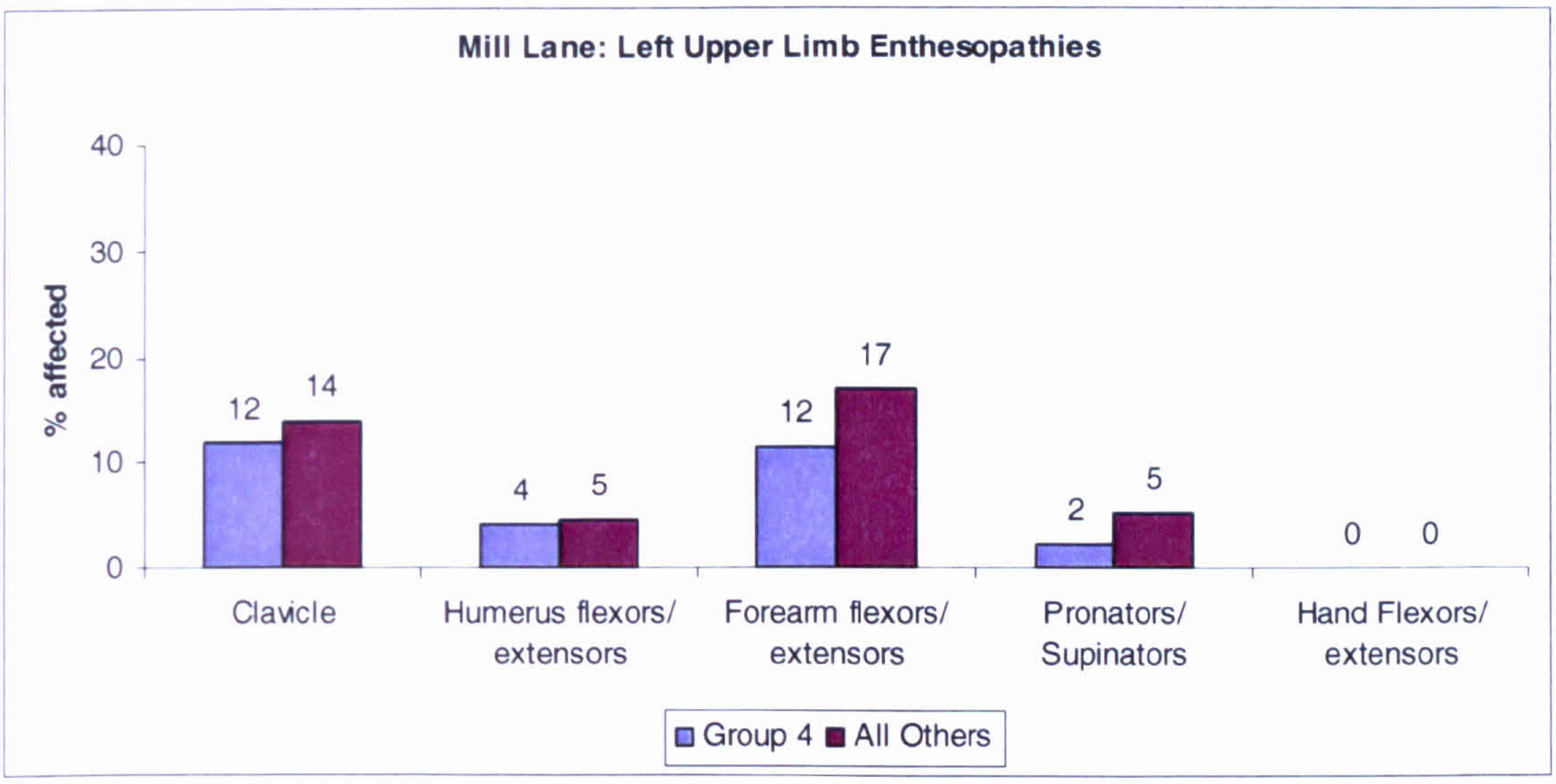


Figure 4.4.2e: The percentage of entheses affected in the left upper limb from Group 4 and all other individuals.

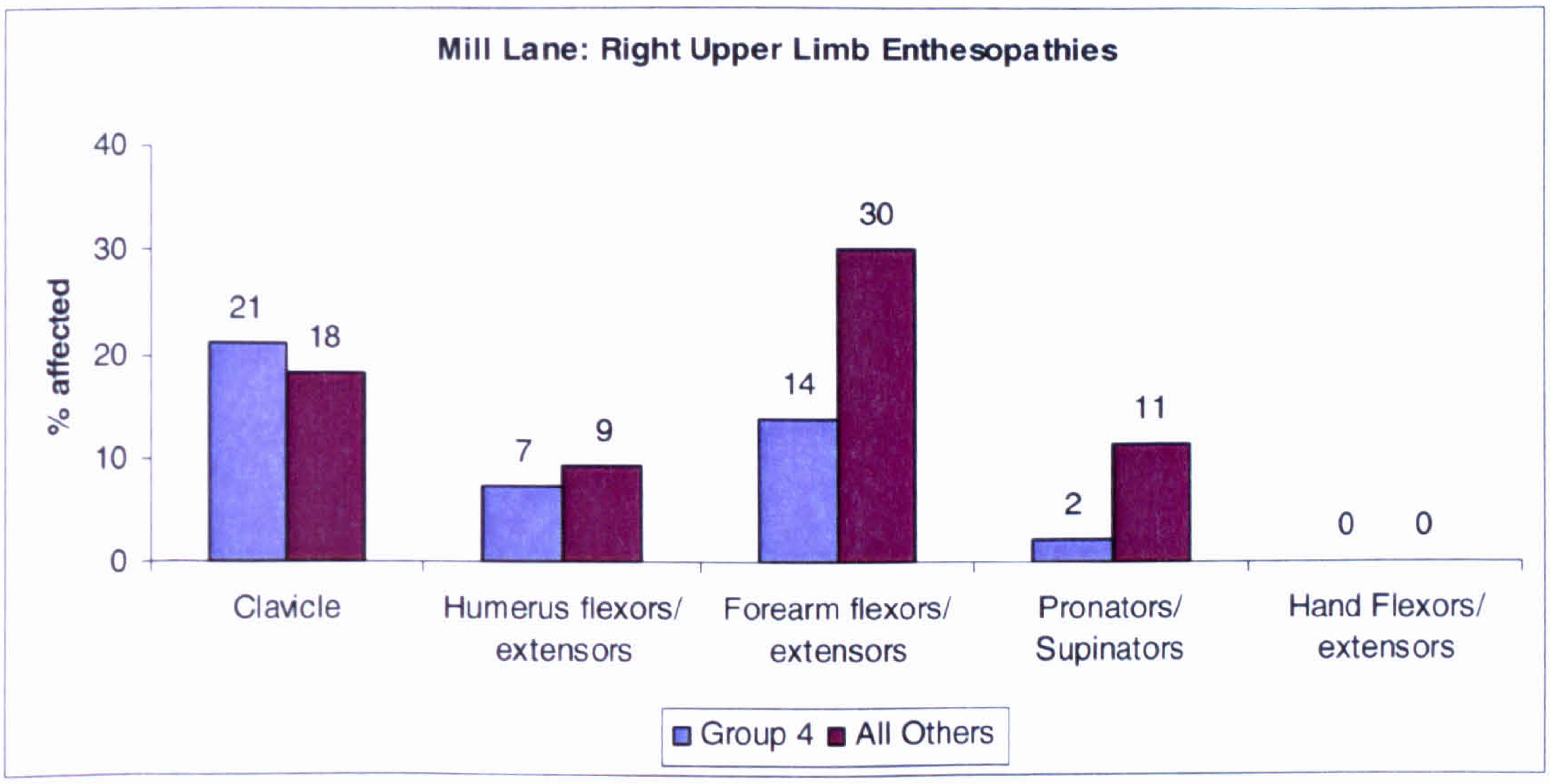


Figure 4.4.2f: The percentage of entheses affected in the right upper limb from Group 4 and all other individuals.

As with the results from the upper limb, the percentages of entheses affected in the lower limb were smaller than those seen at Castledyke. The percentages of possible enthesopathies were rather higher, but did not show as much variation between the artefact groups as the results for enthesopathies, and consequently will not be examined further for this skeletal sample. The numbers of individuals affected were similar to those seen for the upper limb. Group 4 had the lowest percentage of individuals with enthesopathies in the lower limb, and Group 1 had the highest percentage of individuals affected, although this may be affected by the relatively small number of individuals in Group 1 at Norton Mill Lane. Figures 4.4.2g and 4.4.2h show the percentage of entheses with enthesopathies from the left and right sides of the lower limb from each of the artefact groups

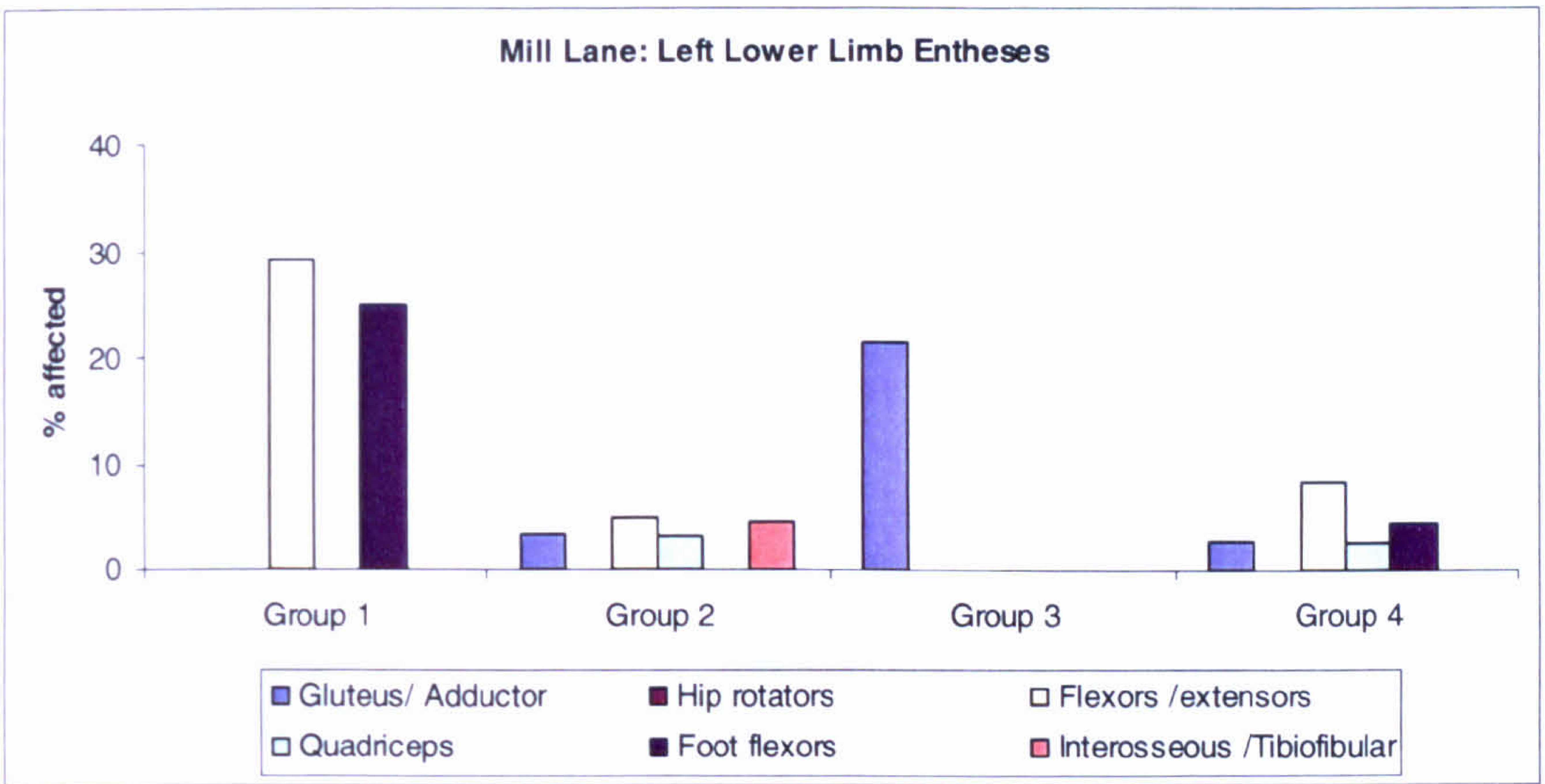


Figure 4.4.2g: The percentages of enthesopathies in the left side of the lower limb each of the artefact groups from Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

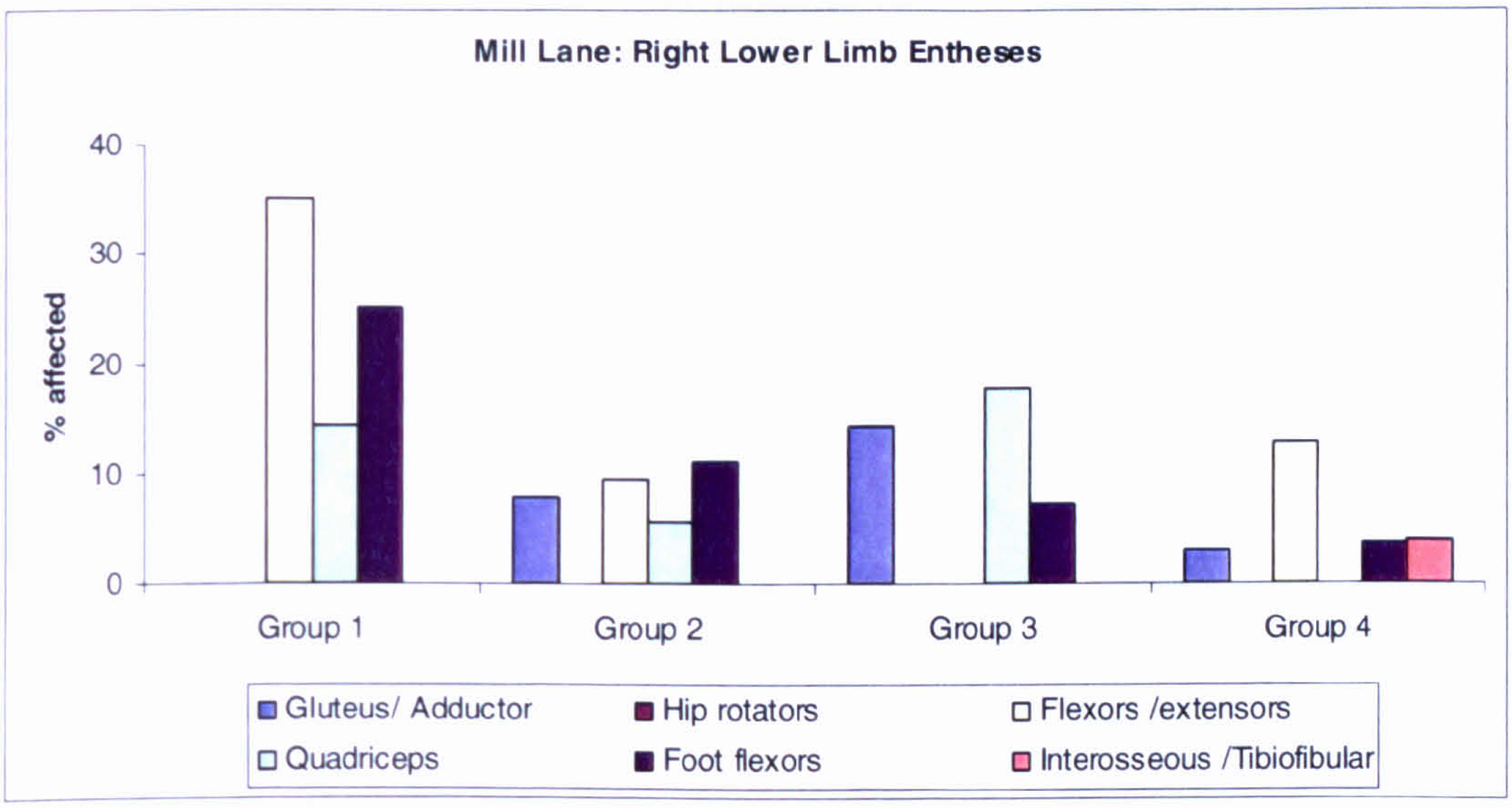


Figure 4.4.2h: The percentages of enthesopathies in the right side of the lower limb each of the artefact groups from Mill Lane. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Group 1 had the highest percentage of changes to the femoral flexors and extensors, and the foot flexors and extensors, but Group 3 had the highest percentage of gluteus and adductor and right quadriceps entheses. However the gluteus and adductor was the only entheses group to be affected in the left side of the lower limb in Group 3 individuals. Group 4 had low levels of changes, as did individuals from Group 2. Figures 4.4.2i and 4.4.2j show the percentage of entheses with changes from the left and right sides of the lower limb from Group 3, compared with all other males

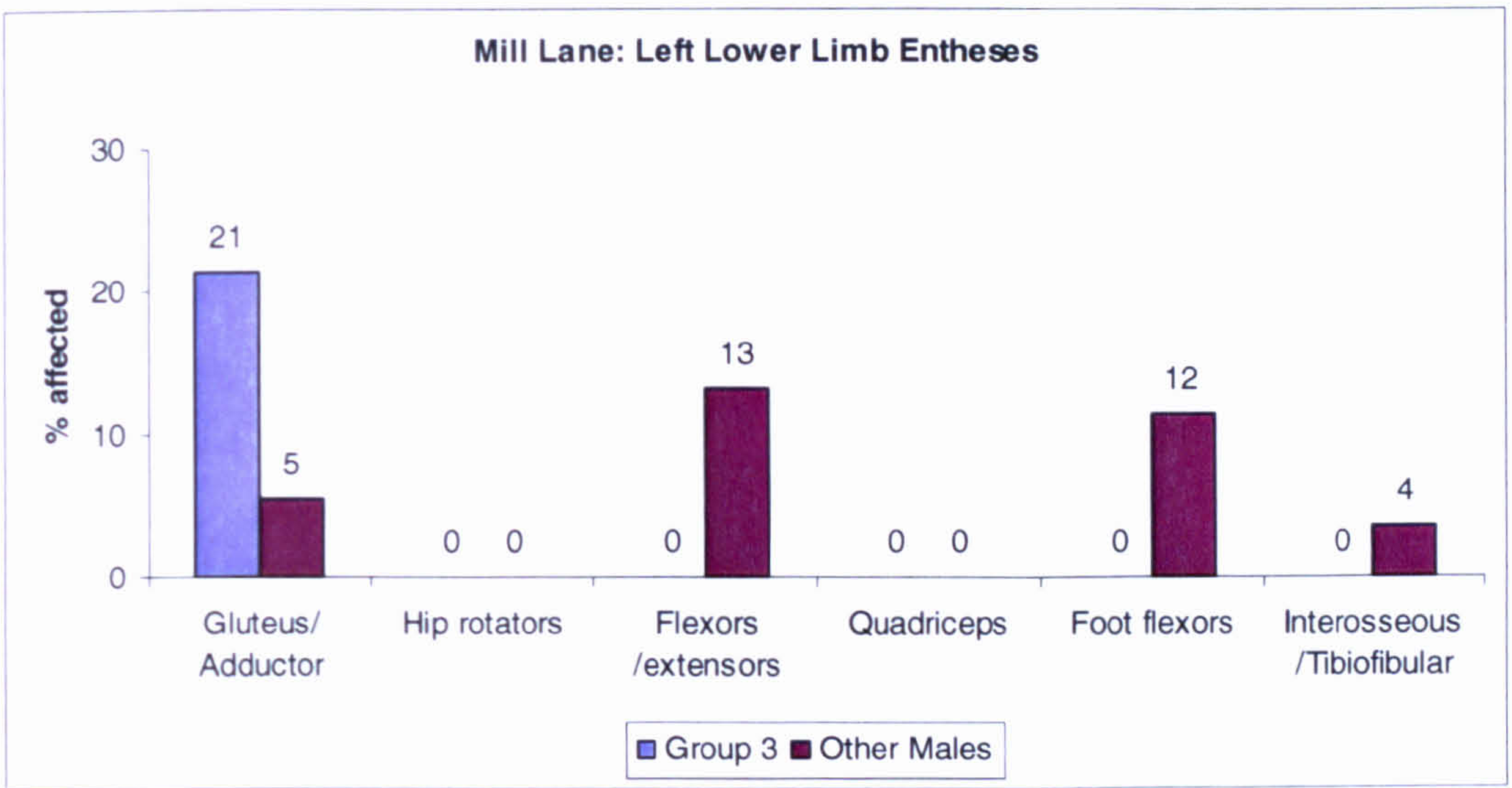


Figure 4.4.2i: The percentage of enthesopathies in the left side of the lower limb from Group 3 and from all other males.

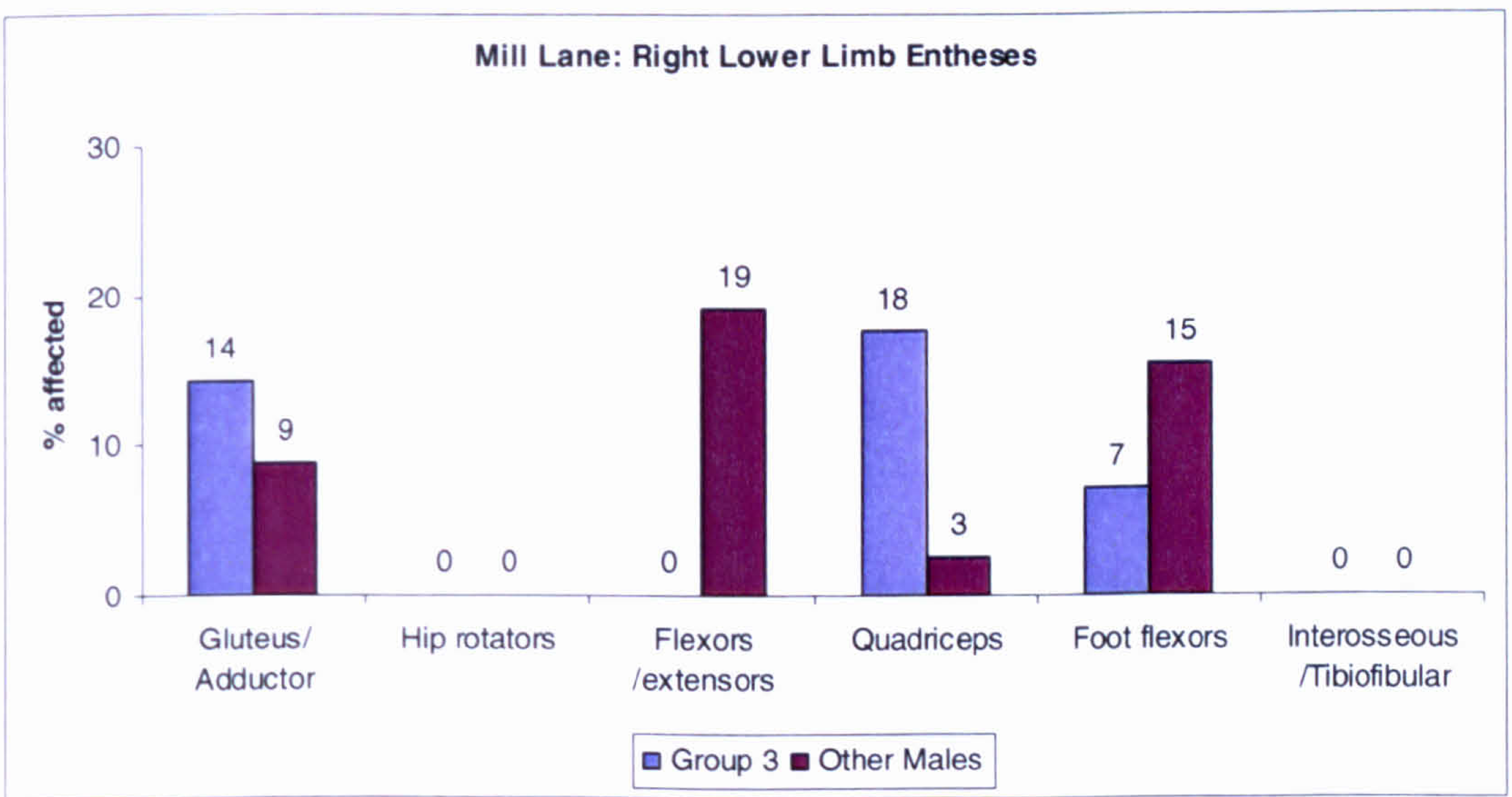


Figure 4.4.2j: The percentage of enthesopathies in the left side of the lower limb from Group 3 and from all other males.

Amongst the Group 3 males the only entheses group with enthesopathies on the left side was the gluteus and adductor, and the percentage of changes in this site was significantly higher than that seen in all other males (chi squared p= <0.001). In the right side of the lower limb, the percentage of gluteus and adductor and quadriceps entheses affected in Group 3 was much higher than in other males, but only the difference between the percentages of quadriceps entheses was statistically significant (chi squared p=<0.001). All other males had higher levels of changes in the femoral and foot flexors and extensor entheses. Figures 4.4.2k and 4.4.2l show the percentage of entheses affected from the left and right sides of the lower limb in Group 4 and all other individuals.

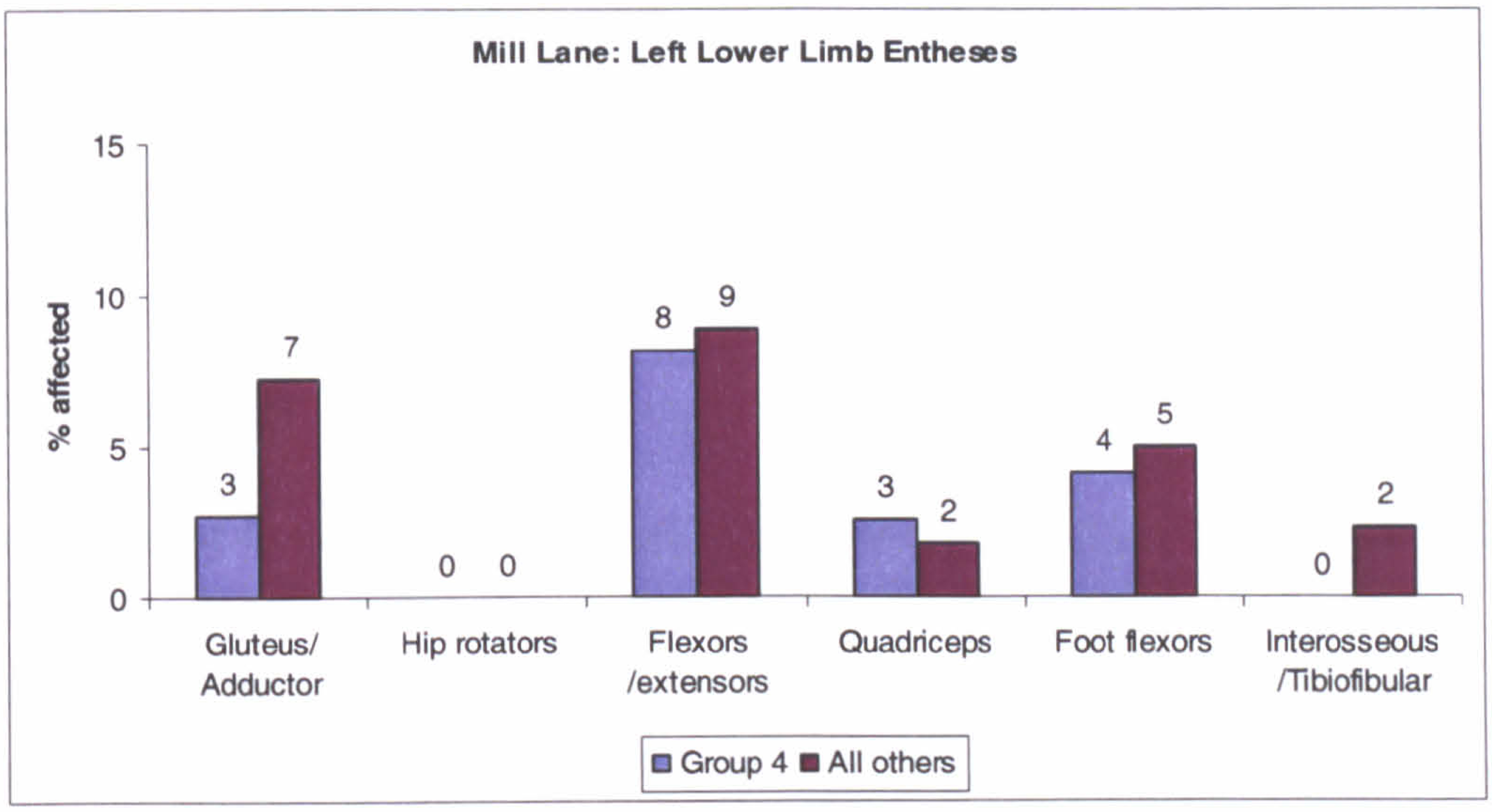


Figure 4.4.2k: The percentage of enthesopathies from the left side of the lower limb in Group 4 and all other individuals from Norton Mill Lane.

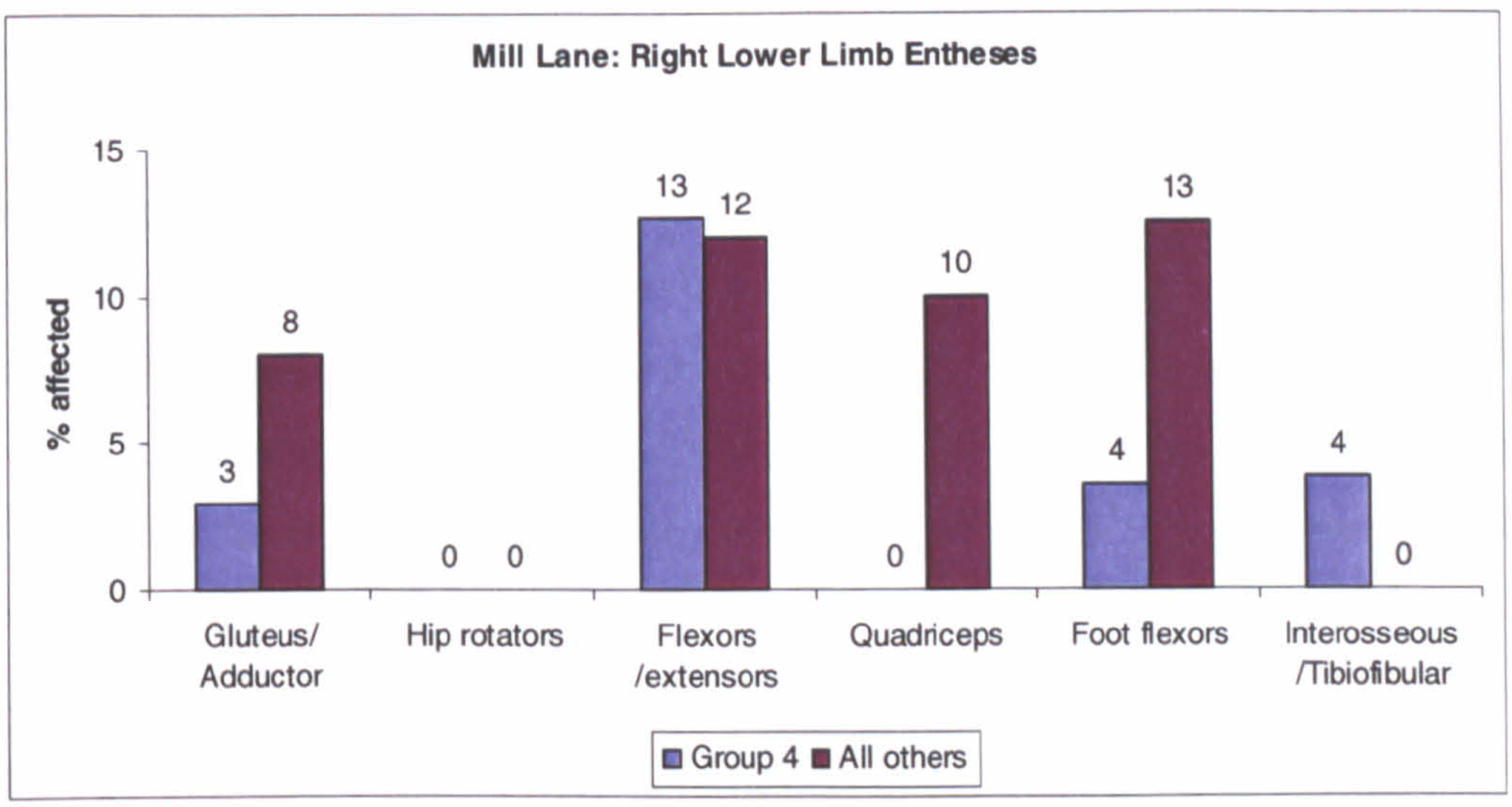


Figure 4.4.2l: The percentage of enthesopathies from the right side of the lower limb in Group 4 and all other individuals from Norton Mill Lane.

In the left side of the lower limb, Group 4 individuals, those with the most elaborate dress fittings and grave artefacts had lower levels of entheses affected, except for the quadriceps entheses where the prevalence was slightly higher in Group 4. In the right side, Group 4 were the only individuals with enthesopathies in the entheses of the interosseous, and the prevalence of changes to the femoral flexor and extensors was slightly higher than in all other individuals, but for the rest of the entheses Group 4 individuals were less frequently affected.

These results show that there were differences in the location and frequency of enthesopathies between the artefact groups at Norton Mill Lane but, despite the similarities in the artefact groups at Norton Mill Lane and Castledyke South, the patterns of enthesopathies seen at these two sites were rather different.

4.4.3: Bamburgh

From the total of 40 individuals from Bamburgh, 58% had enthesopathies and 78% had possible enthesopathies in the upper limb, and 48% had enthesopathies and 65% had possible enthesopathies in the lower limb. Four individuals had all 44 entheses from the upper limbs present, and only two had all 34 entheses present in the lower limbs. Tables showing the number of each entheses observed, and the number and percent of entheses with enthesopathies and possible enthesopathies observed for each side of the upper and lower limbs are given in Appendix 3.3.

Other than in the hand flexors and extensors, the percentage of entheses with possible enthesopathies was higher on the left, but the percentages of entheses with enthesopathies was higher on the right side for all entheses groups. In the lower limb, while the percentages of entheses with changes were much more similar between the left and right sides than in the upper limb, the prevalence of enthesopathies was higher on the right side in the majority of the entheses.

Table 4.4.3a shows the number of individuals present of each sex and the average number of entheses present for observation from the upper and lower limbs, and the average number affected by enthesopathies and possible enthesopathies. The number of entheses from each sex is given in brackets.

Sex	No. of Sk	Upper Limb Present	Upper Limb Enth	Upper Limb ?Enth	Lower Limb Present	Lower Limb Enth	Lower Limb ?Enth
Female	17	31 (531)	8 (128)	12 (199)	24 (414)	5 (93)	8 (136)
Male	23	30 (690)	10 (235)	11 (244)	26 (564)	8 (171)	10 (211)

Table 4.4.3a: The number of females and males with entheses present and the average number of entheses present, with enthesopathies and with possible enthesopathies in the upper and lower limbs. The number of entheses present is given in brackets.

On average the number of entheses with enthesopathies was higher in males than in females in both the upper and lower limbs, but this difference was not significant when tested with single factor ANOVA tests (upper limb $p= 0.3$, lower limb $p= 0.2$). Therefore it is reasonable to combine the data for males and females when examining differences between artefact groups.

i) Enthesopathy, Age and Sex

Table 4.4.3b shows the percentage of entheses from both sides of the upper and lower limbs that were observed with enthesopathies, possible enthesopathies, and the percentage of sites that were not affected (None) in females and males from each of the age groups in the skeletal sample from Bamburgh.

Age Group	Female Enth	Female ?Enth	Female None	Male Enth	Male ?Enth	Male None
Young	3 (6)	20 (41)	77 (154)	21 (35)	26 (44)	53 (89)
Young /Middle	4 (1)	24 (6)	72 (18)	14 (14)	44 (44)	42 (41)
Middle	17 (54)	37 (112)	43 (124)	23 (80)	33 (115)	44 (156)
Older	37 (160)	41 (176)	22 (93)	44 (270)	40 (244)	16 (100)
Adult	0 (0)	0 (0)	0 (0)	32 (7)	36 (8)	32 (7)

Table 4.4.3b: The percentage of entheses from both sides of the upper and lower limbs, in each age group that showed enthesopathies, possible enthesopathy, and no changes in females and males. The number of entheses in each group is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

In both sexes the percentage of enthesopathies increased significantly with age (chi squared $p= 0.01$) but, although the percentage of possible enthesopathies was lowest in the Young age group, the increase in the percentage of these changes was less clearly associated with age

ii) Enthesopathy and Status

Tables showing the number and the percentage of enthesis groups from the left and right sides of the upper land lower limbs that were affected with enthesopathies and possible enthesopathies, and the number and percentage of individuals affected from each of the burial artefact groups in the skeletal sample from Bamburgh are given in Appendix 3.3. The percentages of entheses with enthesopathies and possible enthesopathies were higher at Bamburgh than those seen at Norton Mill Lane, and more comparable with the prevalences seen at Castledyke South.

The percentage of individuals affected was highest in Groups B and C, and lowest in Group D, despite the fact that this group predominantly included older individuals. This suggests that a factor other than age was influential upon the development of enthesopathies. There were clear differences in the prevalence of enthesopathies in the upper limb, particularly on the right side, but as in the other sites the prevalence of possible enthesopathies was more similar between the artefact groups, and all individuals from the four artefact groups were affected, and hence possible enthesopathies will not be examined further.

Figure 4.4.3a and Figure 4.4.3b show the percentage of enthesopathies from the left and right sides of the upper limb in each of the artefact groups.

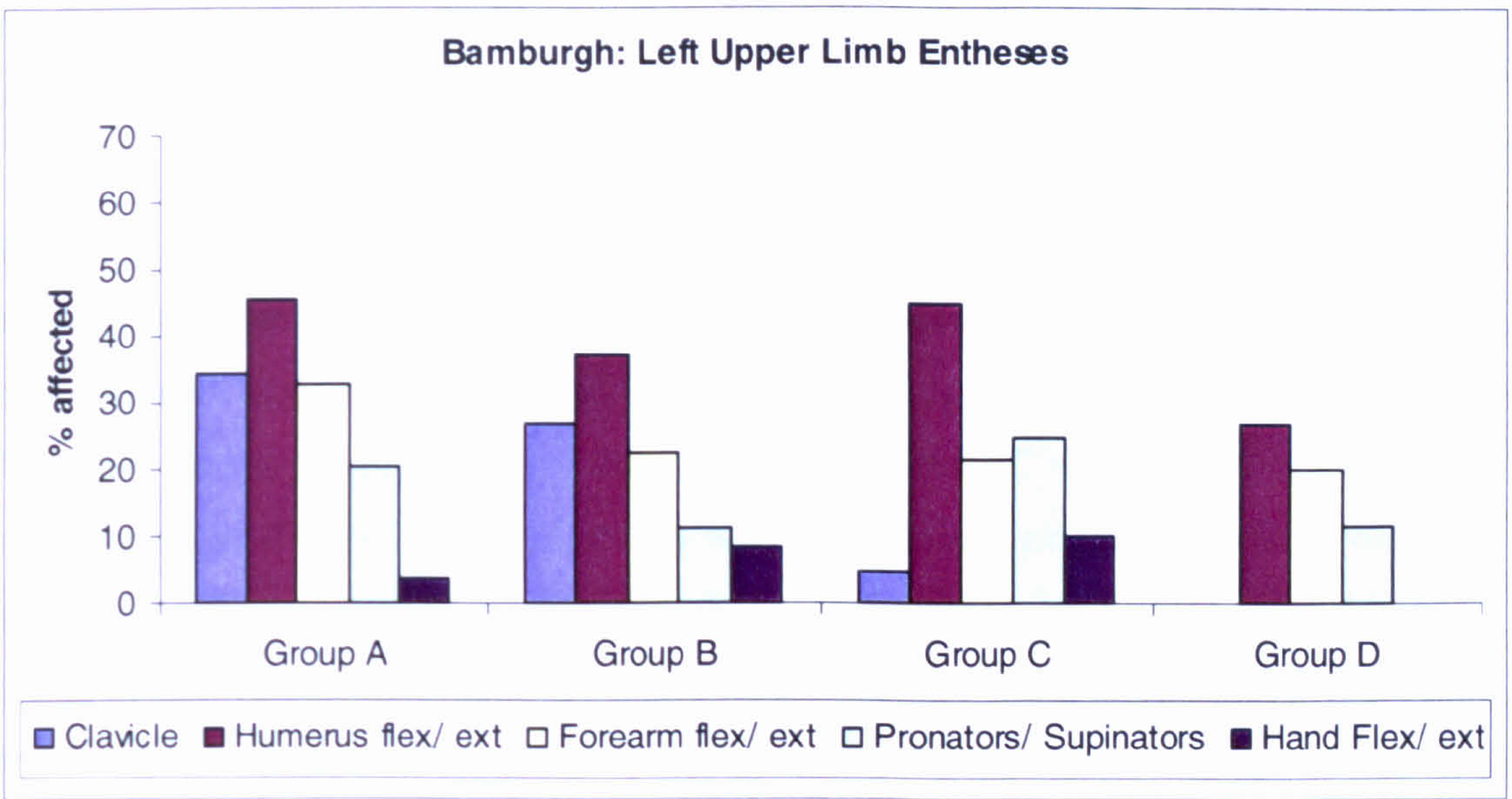


Figure 4.4.3a: The percentages of enthesopathies in the left side of the upper limb each of the artefact groups from Bamburgh Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

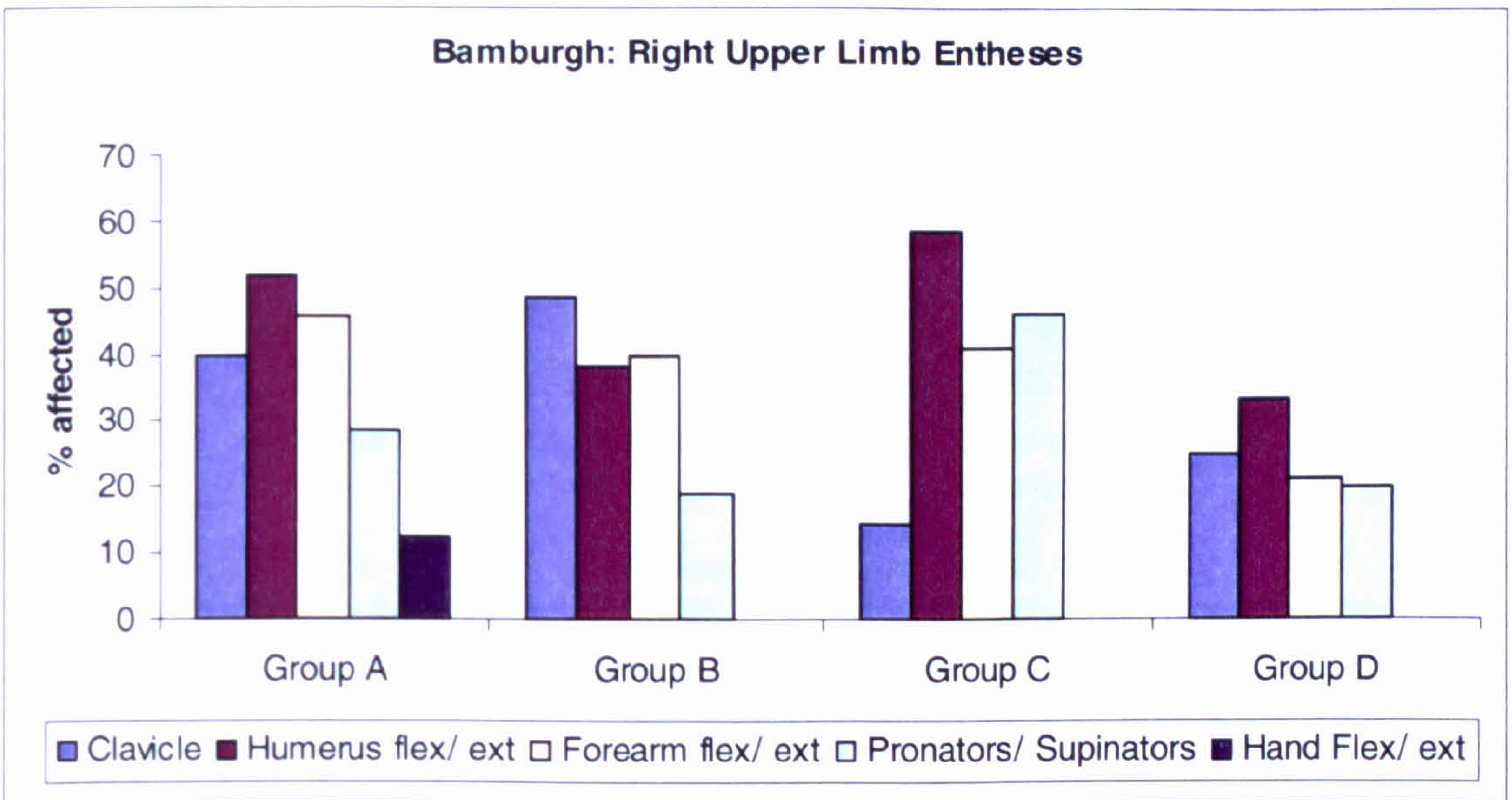


Figure 4.4.3b: The percentages of enthesopathies in the left side of the upper limb each of the artefact groups from Bamburgh Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

From these figures it is clear that there were differences in the location and frequency of entheses that were affected. Group D had relatively low levels of enthesopathies, while Group C had high levels of changes to the humeral flexors, pronators and supinators and forearm flexors, particularly on the right side. However, Group C had the lowest prevalence of changes to the clavicle on the right side. These patterns are similar to those seen in Group 3 at Castledyke South, and the patterns from Bamburgh groups A and B were very similar to those seen in Castledyke groups 1 and 2.

In order to exclude the possibility that the differences between Group C and Group D were primarily due to sex, Group C was compared with all other males and Group D was compared with all other females. Figures 4.4.3c and 4.4.3d show the percentage of entheses affected in the left and right sides of the upper limb in Group C males and all other males from Bamburgh. Group C had significantly lower percentages of enthesopathies from the both sides of clavicle than all other males (chi squared: left side p= 0.0002, right side p= 0.00008), and lower percentages of enthesopathies on the left side in all regions except for the hand flexors and extensors.

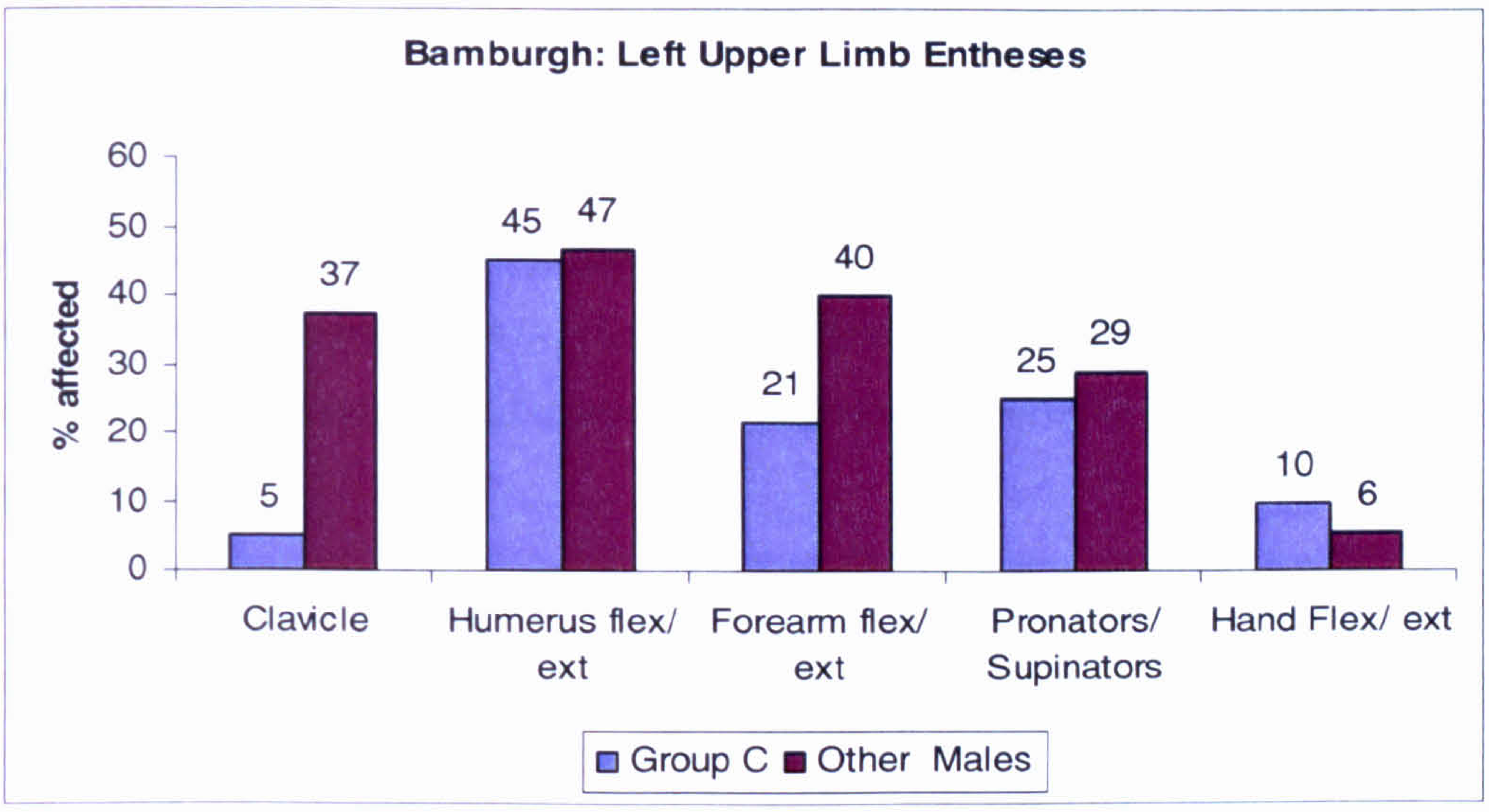


Figure 4.4.3c: The percentage of enthesopathies in the left upper limb from Group C and all other males from Bamburgh

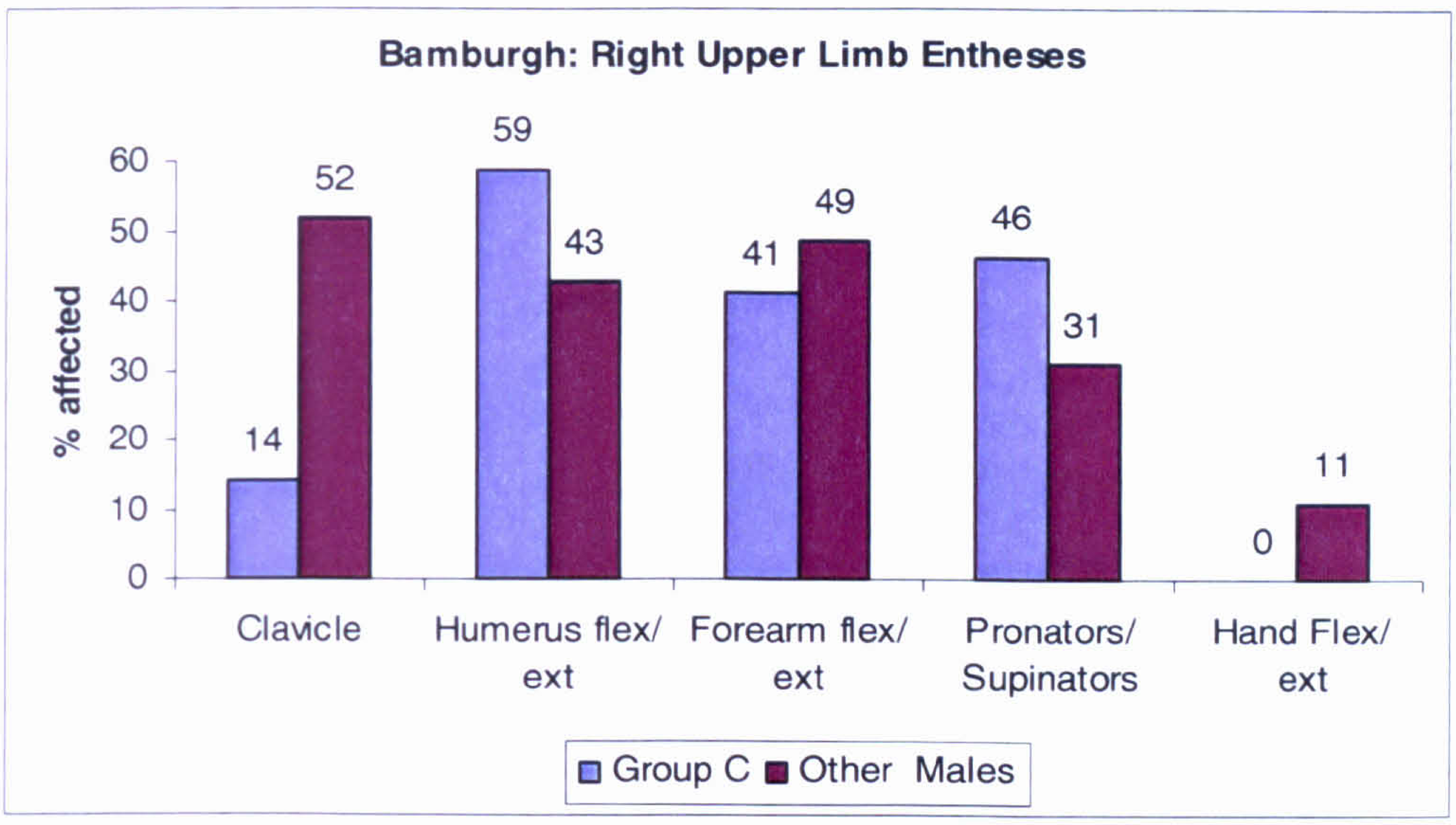


Figure 4.4.3d: The percentage of enthesopathies in the right upper limb from Group C and all other males from Bamburgh

In the right upper limb, Group C males had significantly higher percentages of humeral flexor and extensor entheses affected than all other males (chi squared p= 0.02), and the percentage of changes to the pronator and supinators entheses was also significantly higher in Group C (p=0.005). Figures 4.4.3e and 4.4.3f show the percentage of entheses affected from the left and right sides of the upper limb in Group D and females from all other artefact groups.

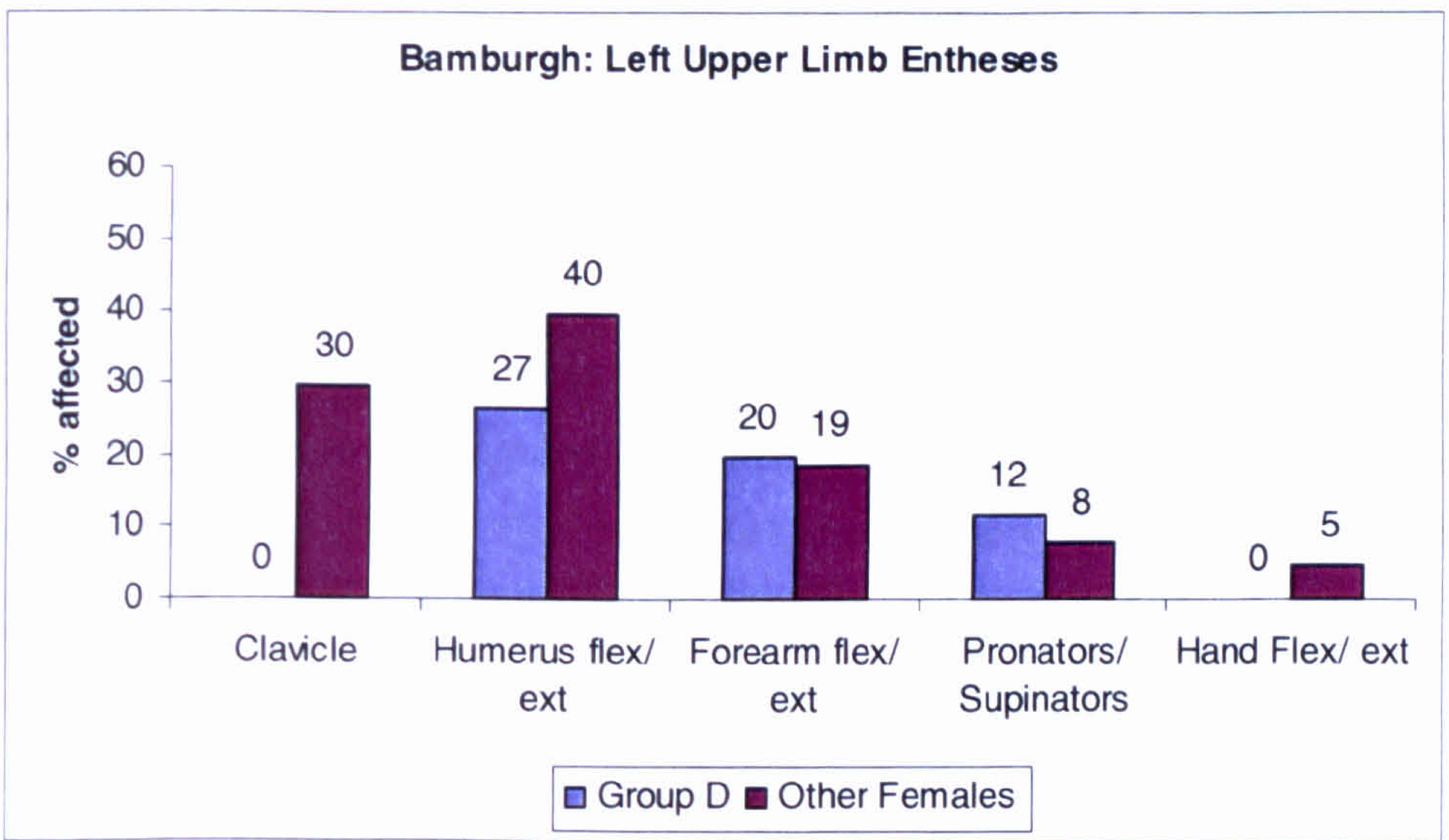


Figure 4.4.3e: The percentage of enthesopathies in the left upper limb from Group D and all other females from Bamburgh

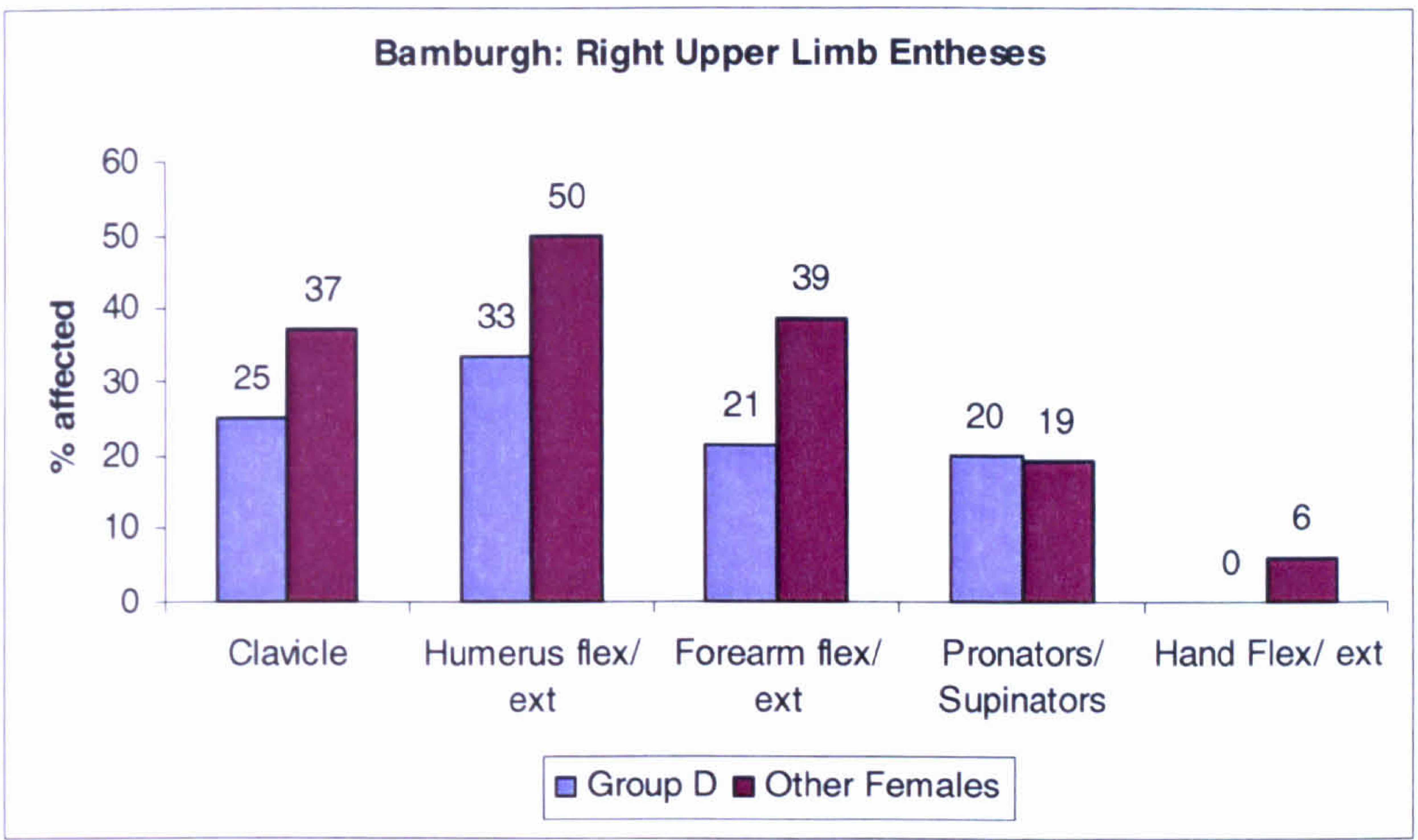


Figure 4.4.3f: The percentage of enthesopathies in the right upper limb from Group D and all other females from Bamburgh

These figures show that Group D individuals had lower levels of enthesopathies than other females in most of the regions examined, except for the left forearm flexors and the pronators and supinators from both sides of the upper limb. Group D individuals had no enthesopathies of the hand flexors and extensors, or the left clavicle.

Groups A and C were the only artefact groups to have all entheses affected in both sides of the lower limb, but Group D had the highest prevalence of changes in the gluteus and adductor on the left side and the femoral flexors on the right side. As was seen in the results for the upper limb, Group C had the highest percentage of individuals with enthesopathies in the lower limb, but the lowest percentage of individuals affected was seen in Group B.

In the lower limb, there was less variation in the location of possible enthesopathies than enthesopathies, with all groups being affected in all locations, and all individuals having at least one enthesis group affected. Groups C and D had the highest percentage of entheses with possible enthesopathies in the lower limb. Unlike the upper limb there was less marked lateralisation of changes to the entheses from the lower limb, suggesting that the lateralisation of enthesopathies in the upper limb was due to differences in use of the upper limb rather than other systemic factors. As possible enthesopathies appear to be less indicative of variation between the groups these changes will not be examined further.

Figures 4.4.3g and 4.4.3h shows the percentage of entheses with enthesopathies from the left and right sides of the lower limb from each of the artefact groups.

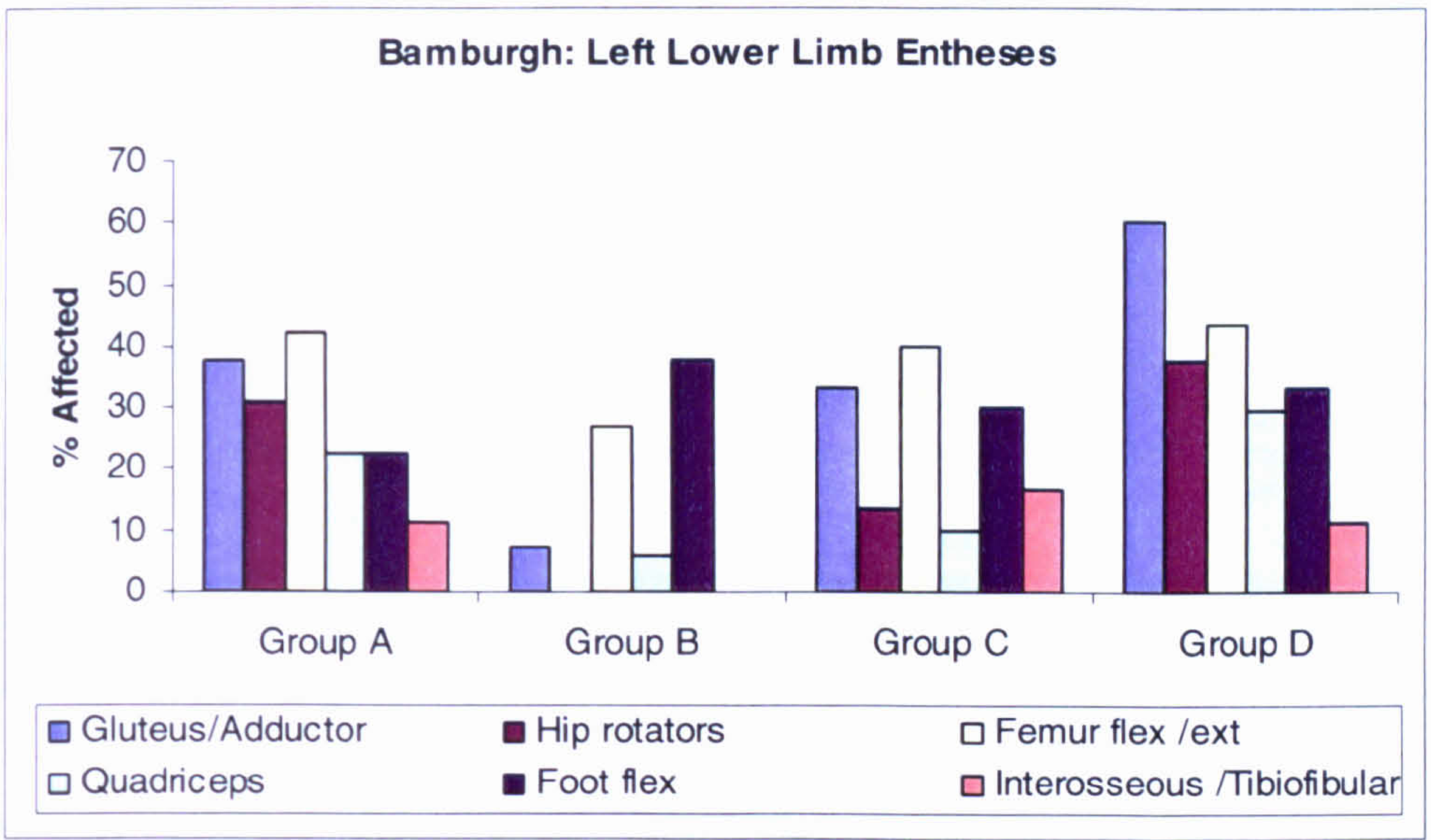


Figure 4.4.3g: The percentage of enthesopathies in the left side of the lower limb in each of the artefact groups from Bamburgh. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C – multiple animal bones, Group D – Multiple iron objects.

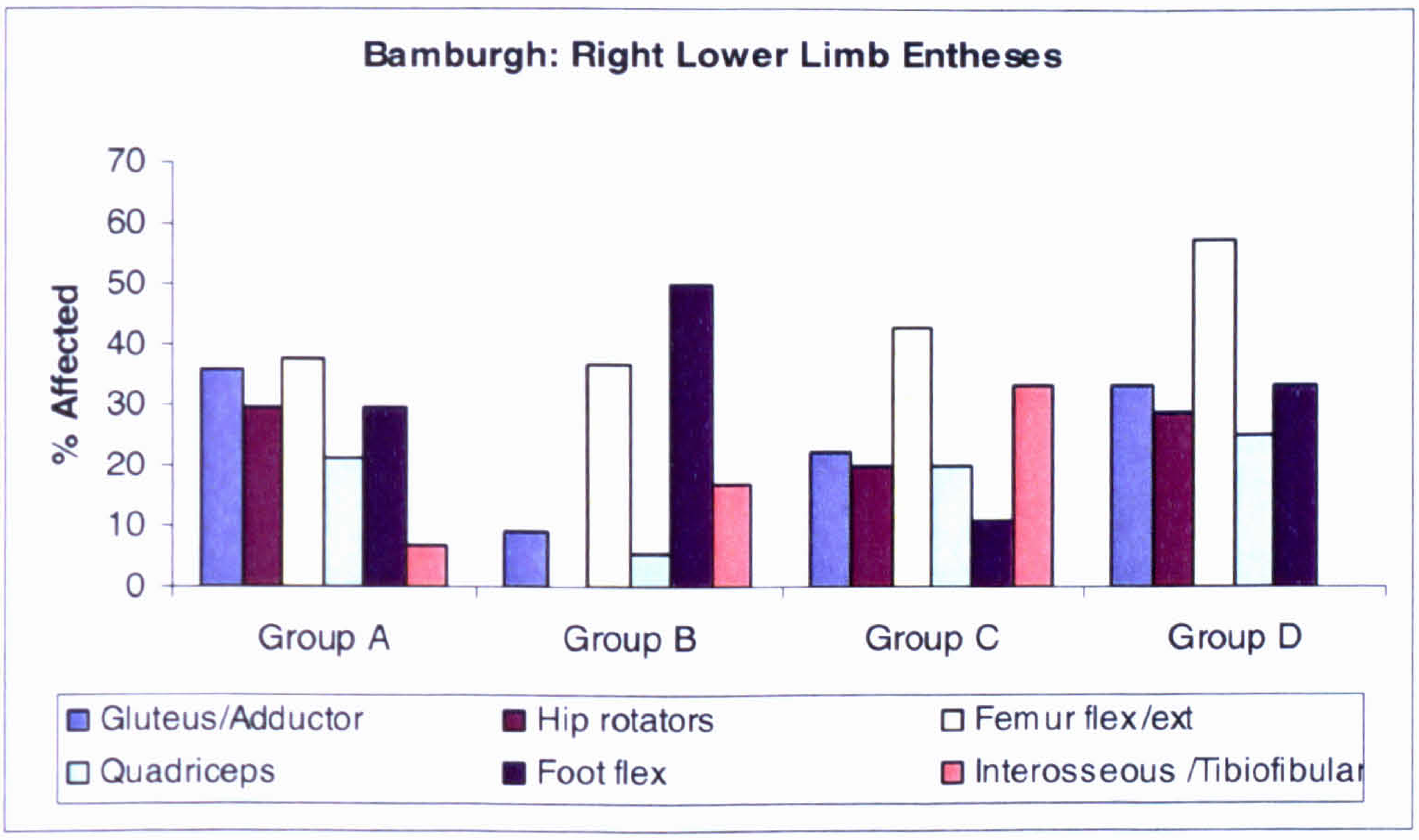


Figure 4.4.3.h: The percentage of enthesopathies in the right side of the lower limb in each of the artefact groups from Bamburgh. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C – multiple animal bones, Group D – Multiple iron objects.

Figures 4.4.3i and 4.4.3j show the percentage of entheses with changes from the left and right sides of the lower limb from Group C, compared with all other males.

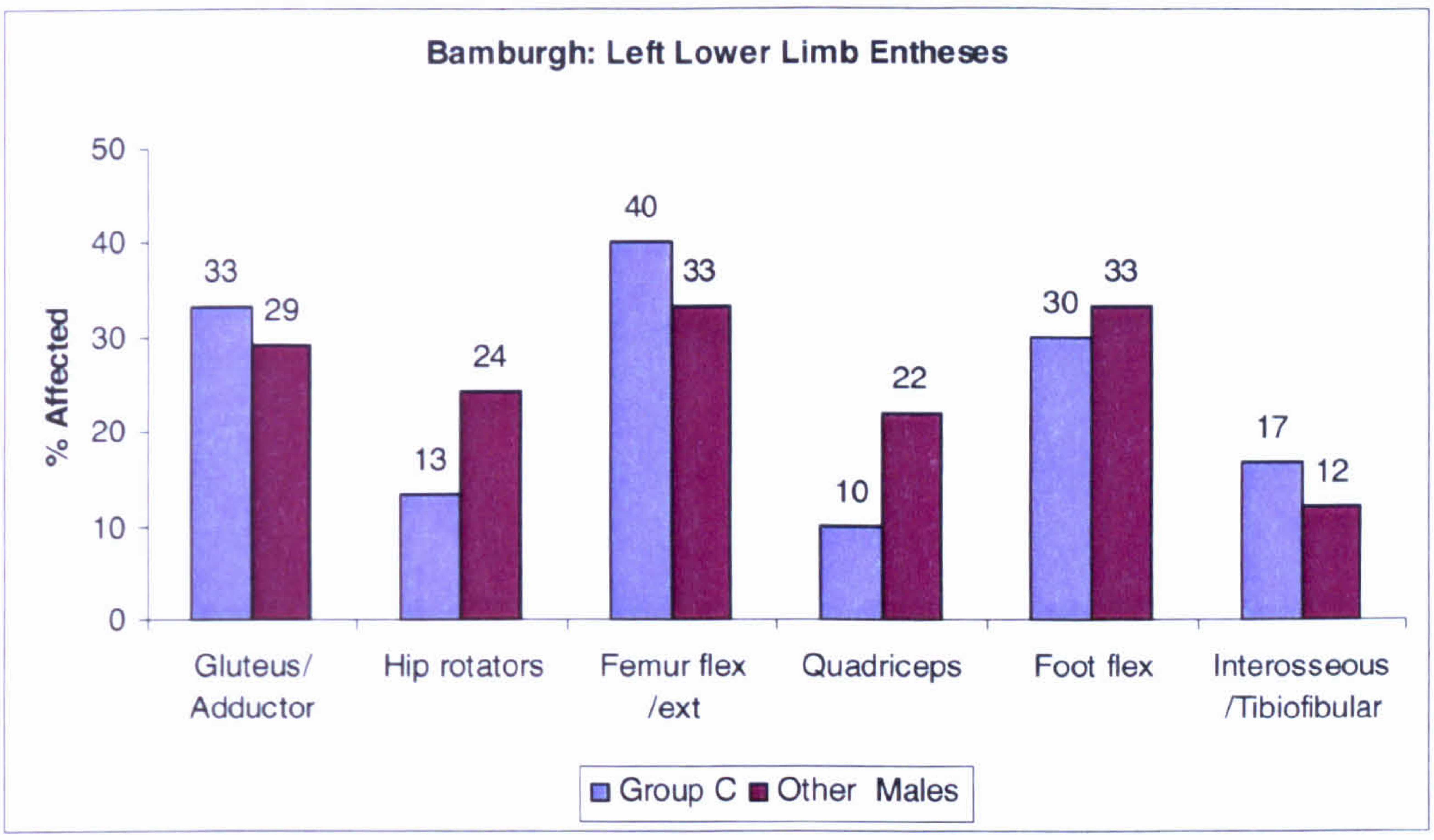


Figure 4.4.3i: The percentage of enthesopathies in the left side of the lower limb in Group C and all other males from Bamburgh

On both sides of the lower limb, Group C had higher percentages of femoral flexors and tibio-fibular interosseous entheses affected than all other males, although only the difference in percentage of interosseous membrane entheses was statistically significant (chi squared: left side $p= 0.03$, right side $p= <0.001$). In the right side of the lower limb the percentage of foot flexors affected was significantly lower in Group C than in all other males (chi squared $p= >0.001$), and on the left side the percentage of quadriceps enthesopathies was also significantly lower in Group C ($p=0.03$).

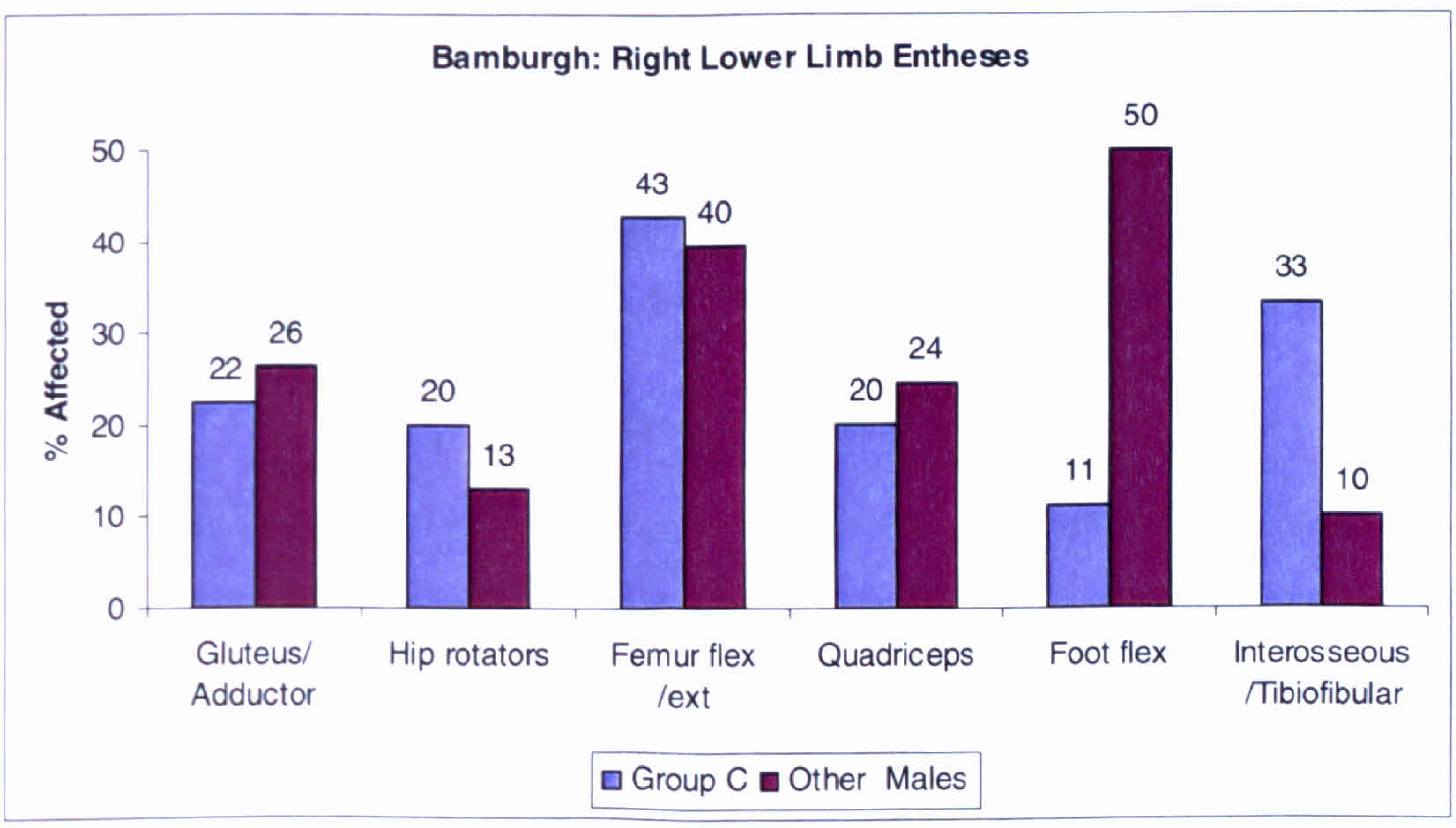


Figure 4.4.3j: The percentage of enthesopathies in the right side of the lower limb in Group C and all other males from Bamburgh

Figures 4.4.3kand 4.4.3l show the percentage of entheses with changes from the left and right sides of the lower limb from Group D, compared with all other females.

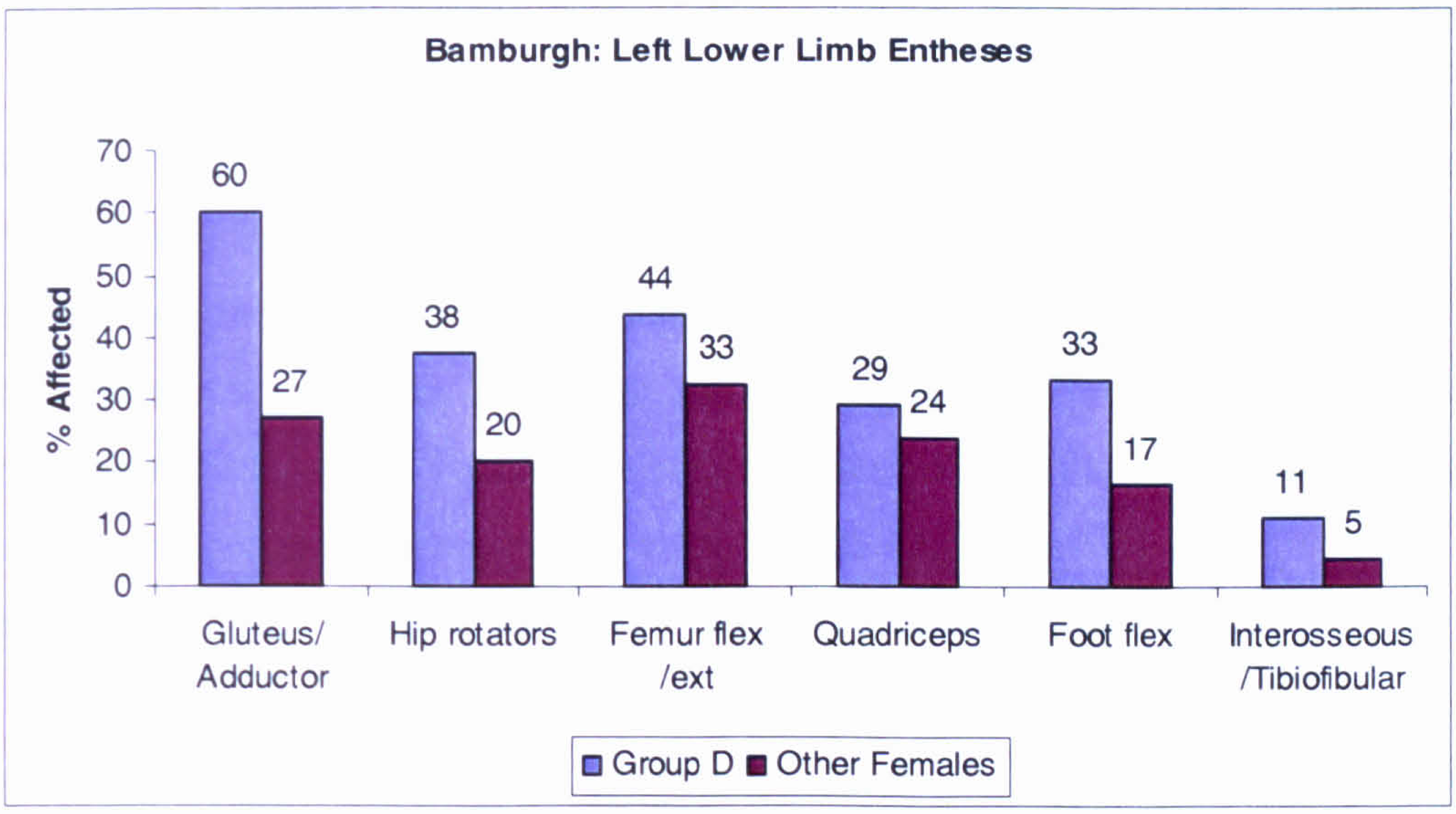


Figure 4.4.3k: The percentage of enthesopathies from the left side of the lower limb from Group D and all other females.

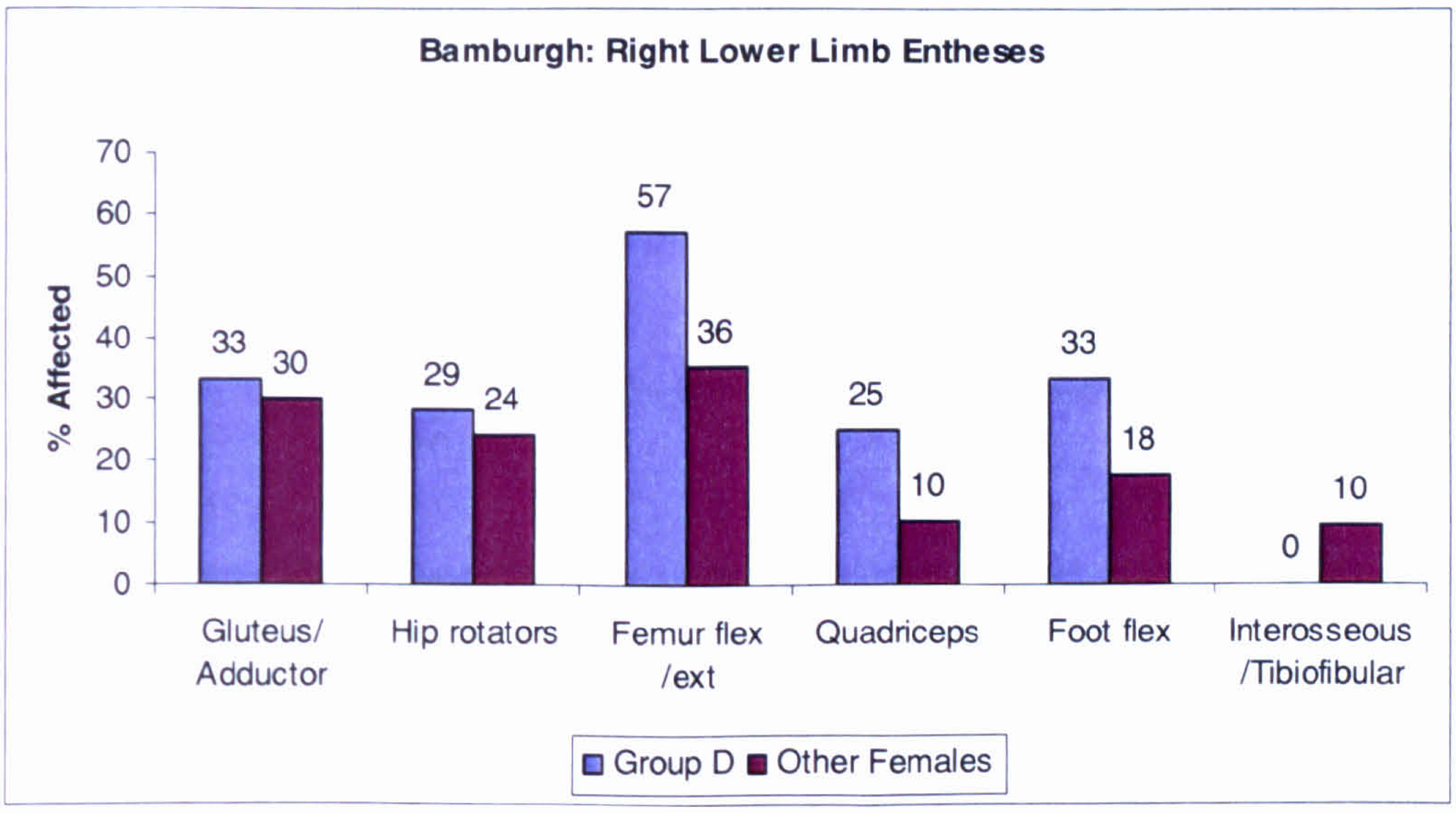


Figure 4.4.3l: The percentage of enthesopathies from the right side of the lower limb from Group D and all other females.

Group D individuals from Bamburgh had higher prevalences of enthesopathies in the lower limb than all other females, in all entheses examined with the exception of the right interosseous, a pattern that was similar to that seen in Group 4 individuals from Castledyke.

However, none of the differences seen between Group D and all other females at Bamburgh were statistically significant.

4.4.4: Norton Bishopsmill

Of the 40 individuals examined from Norton Bishopsmill, one had all 44 entheses present in the upper limb and eight individuals had all 34 entheses present from the lower limb. Six percent of the individuals examined had enthesopathies in the upper limb, and 47% had possible enthesopathies. In the lower limb, 3% of the sample had enthesopathies and 38% had possible enthesopathies. Tables showing the number of each entheses observed, and the number and percent of entheses with enthesopathies and possible enthesopathies observed for each side of the upper and lower limbs are given in Appendix 3.4.

The prevalence of enthesopathies and possible enthesopathies in both the upper and lower limbs was much lower in the Norton Bishopsmill sample than in the other sites, and there was less marked lateralisation of involvement than seen in some of the other samples. Table 4.4.4a shows the number of individuals present of each sex and the average number of entheses present in the upper and lower limbs, and the average number affected by enthesopathies and possible enthesopathies. The number of entheses from each sex is given in brackets.

	No. of	Upper Limb			Lower Limb		
Sex	Sk	**Present**	**Enth**	**?Enth**	**Present**	**Enth**	**?Enth**
Female	17	25 (319)	1 (16)	9 (116)	27 (461)	1 (23)	8 (133)
Male	22	21 (436)	2 (38)	6 (124)	27 (597)	1 (29)	9 (197)

Table 4.4.4b: The number of females and males with entheses present and the average number of entheses present, with enthesopathies and with possible enthesopathies in the upper and lower limbs. The number of entheses is given in brackets.

At Norton Bishopsmill the average number of entheses with enthesopathies and possible enthesopathies was very similar in males and females in the upper and lower limbs. The average numbers of changes were also much lower than those seen at the other sites, even though the average numbers of entheses present for examination were not particularly small. This suggests that there was a factor other than poor preservation of the skeletal material affecting the prevalence of enthesopathies in this skeletal sample.

i) Enthesopathy, Age and Sex

Table 4.4.4b shows the percentage of entheses from both sides of the upper and lower limbs that were observed with enthesopathies, possible enthesopathies, and the percentage of sites that were not affected (None) in females and males from each of the age groups in the skeletal sample from Norton Bishopsmill. No entheses were observed from females in the "Adult" age group. Amongst the males, the increase in the percentage of enthesopathies and possible enthesopathies with increasing age was significant (chi squared; enthesopathies p=0.01, possible enthesopathies p= 0.01); however, amongst the females only the difference in possible enthesopathies was significantly different between the age groups (p=0.01). This suggests that factors other than age were more influential upon the development of enthesopathies in females.

Age Group	Female Enth	Female ?Enth	Female None	Male Enth	Male ?Enth	Male None
Young	4 (10)	16 (38)	80 (196)	5 (5)	17 (16)	78 (76)
Young /Middle	6 (4)	19 (12)	75 (49)	3 (5)	28 (49)	69 (122)
Middle	6 (16)	44 (120)	51 (139)	8 (21)	38 (105)	54 (150)
Older	5 (9)	40 (79)	55 (108)	8 (35)	32 (140)	60 (265)
Adult	0 (0)	0 (0)	0 (0)	2 (1)	25 (11)	73 (32)

Table 4.5.4b: The percentage of entheses from both sides of the upper and lower limbs, in each age group that showed enthesopathies, possible enthesopathy, and no changes in females and males. The number of entheses in each group is given in brackets. Age Groups: Young = 17-25 years, Young/Middle = 26-30 years, Middle = 31-40 years, Older = 41+ years, Adult = could not be aged precisely.

ii) Enthesopathy and Status

Tables showing the number and the percentage of enthesis groups from the left and right sides of the upper land lower limbs that were affected with enthesopathies and possible enthesopathies, and the number and percentage of individuals affected from each of the burial artefact groups in the skeletal sample from Norton Bishopsmill are given in Appendix 3.4. There were only three individuals from Group B and two from Group C with entheses present in the upper limbs so these groups were combined to increase sample size.

In Group A, the percentage of enthesopathies tended to be higher on the right side than on the left, but in Groups B and C and Group D there was much more variation. All of the individuals from Group D had at least one entheses group with enthesopathies or possible enthesopathies in the upper limb, while the percentage of individuals affected by enthesopathies was lowest in Group A. Possible enthesopathies were more frequent, but again Group A was the only group to show any clear lateralisation of changes. The prevalence of possible enthesopathies was relatively high in Group D in comparison with the other groups. As the frequency of enthesopathies and possible enthesopathies was so low at Norton Bishopsmill, in order to compare the results between the artefact groups, the results for enthesopathies and possible enthesopathies were pooled.

Figure 4.4.4a shows the percentage of all changes in the left side of the upper limb, from each of the artefact groups, and Figure 4.4.4b shows the results for the right side of the upper limb. These figures show that the percentages of entheses affected was very similar in Group A particularly on the left side, while Groups B and C and Group D showed more variation in the entheses that were affected. Group D had the highest frequency of changes in all entheses, except for the clavicle, which was most frequently affected in Group A. These results are in contrast with those from the other three sites, where the individuals with the most complex and varied burial artefacts tended to have the lowest percentages of entheses affected by changes.

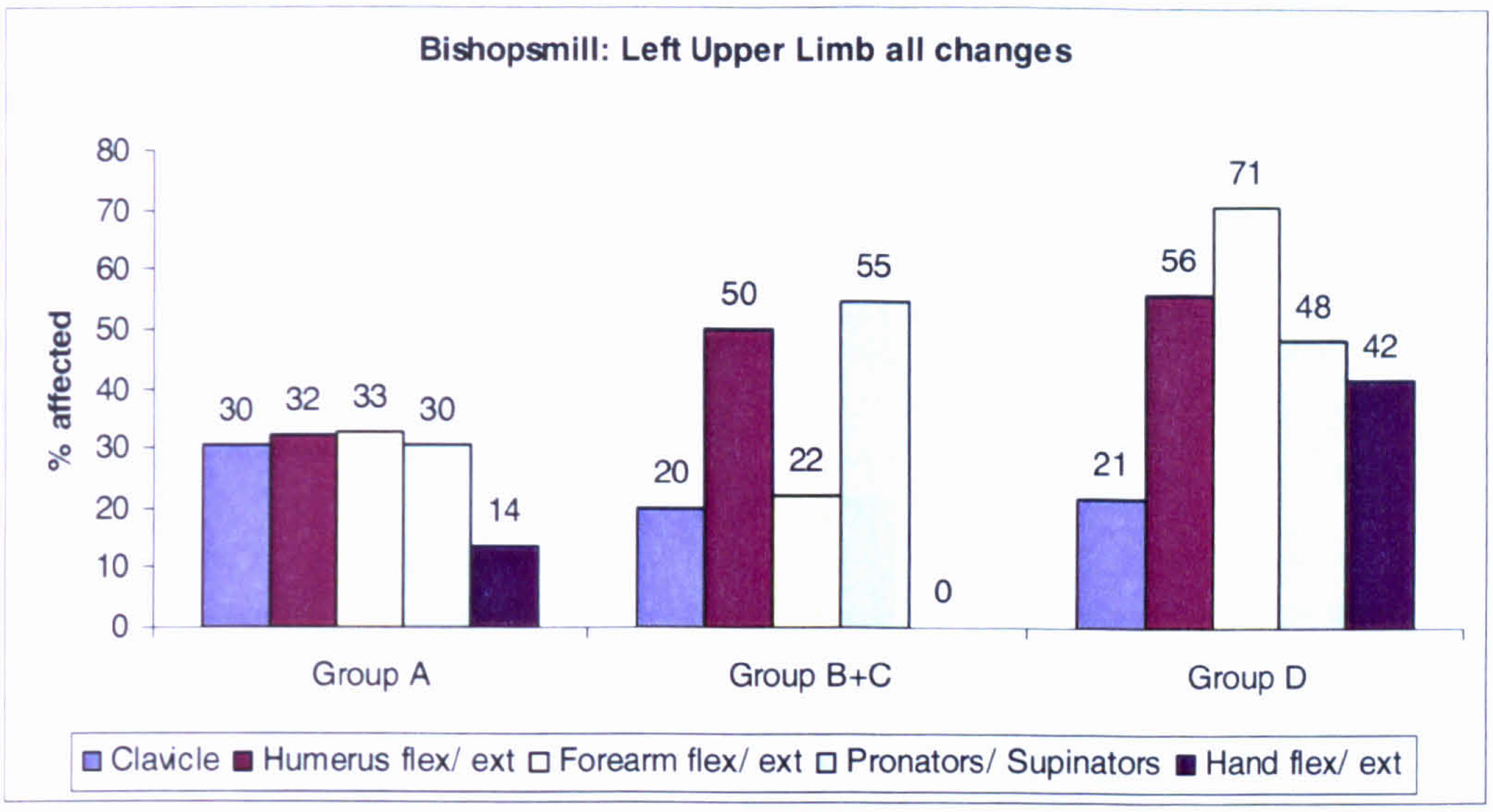


Figure 4.4.4a: The percentage of enthesopathies and possible enthesopathies in the left upper limb from each artefact group from Norton Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – pottery, worked stone or flint, Group D – iron objects or coffin fittings.

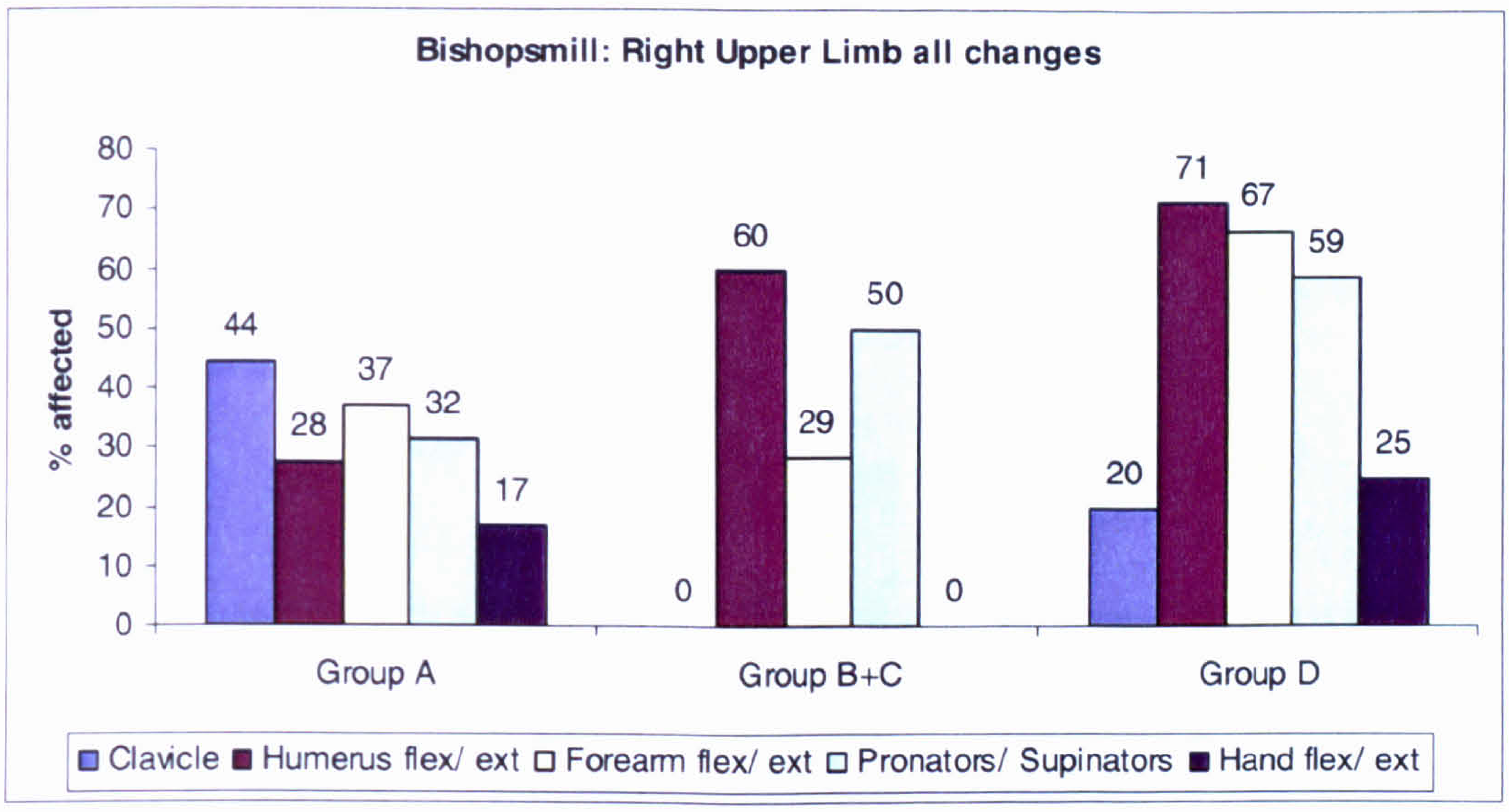


Figure 4.4.4b: The percentage of enthesopathies and possible enthesopathies in the left upper limb from each artefact group from Norton Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – pottery, worked stone or flint, Group D – iron objects or coffin fittings.

The results for Group A were rather different to those from the other artefact groups, and as Group A was considerably larger than the other artefact groups (24 individuals with entheses present in Group A, five in Groups B and C and six in Group D), the results from Group A were compared with all other individuals from Norton Bishopsmill, to establish if the variations in patterns of enthesopathies were an artefact of sample size.

Figures 4.4.4dc and 4.4.4d show the percentage of changes to the entheses observed in the left and right sides of the upper limb from Group A and all other individuals.

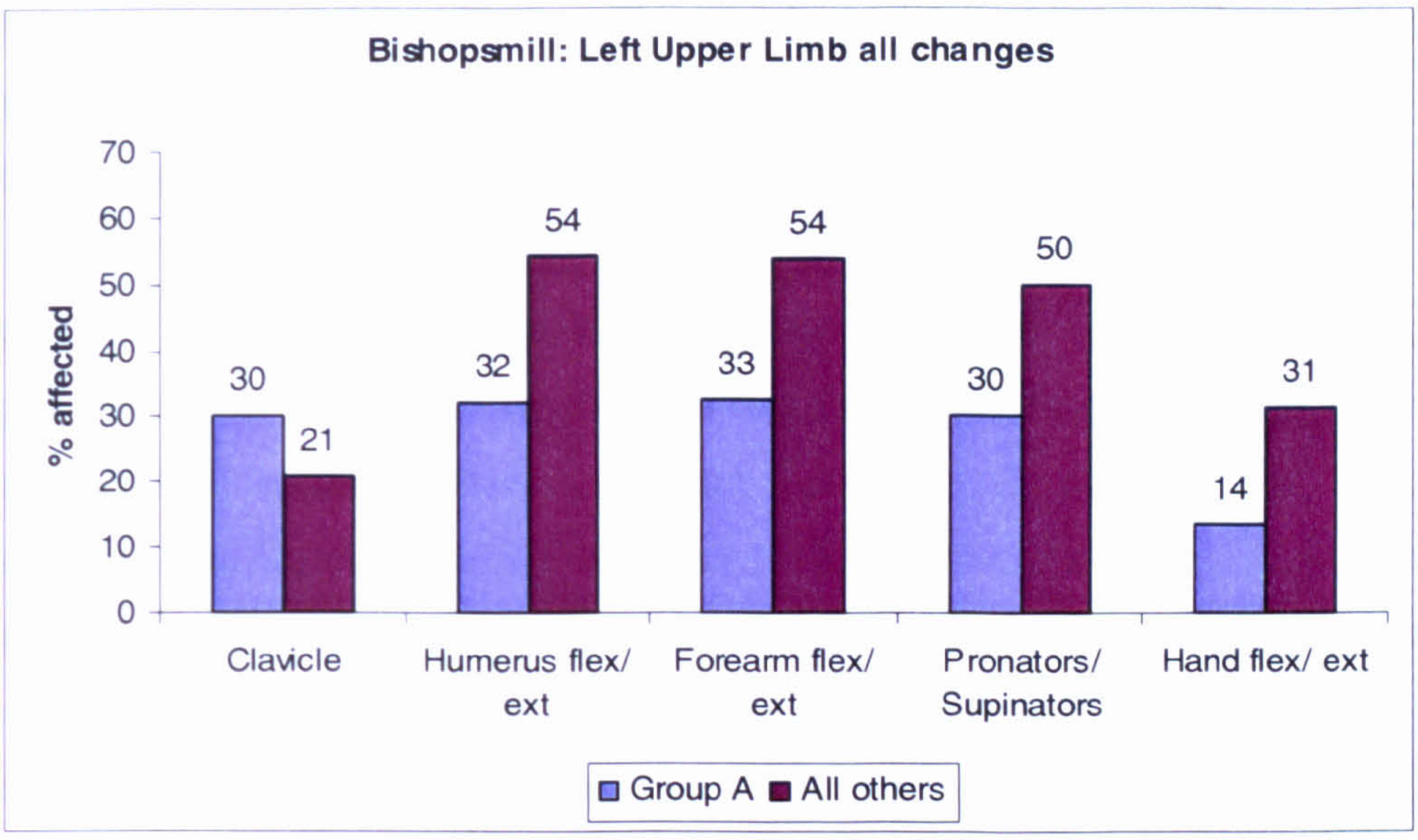


Figure 4.4.4c: The percentage of changes to the entheses on the left side of the upper limb from Group A and all other adults from Norton Bishopsmill

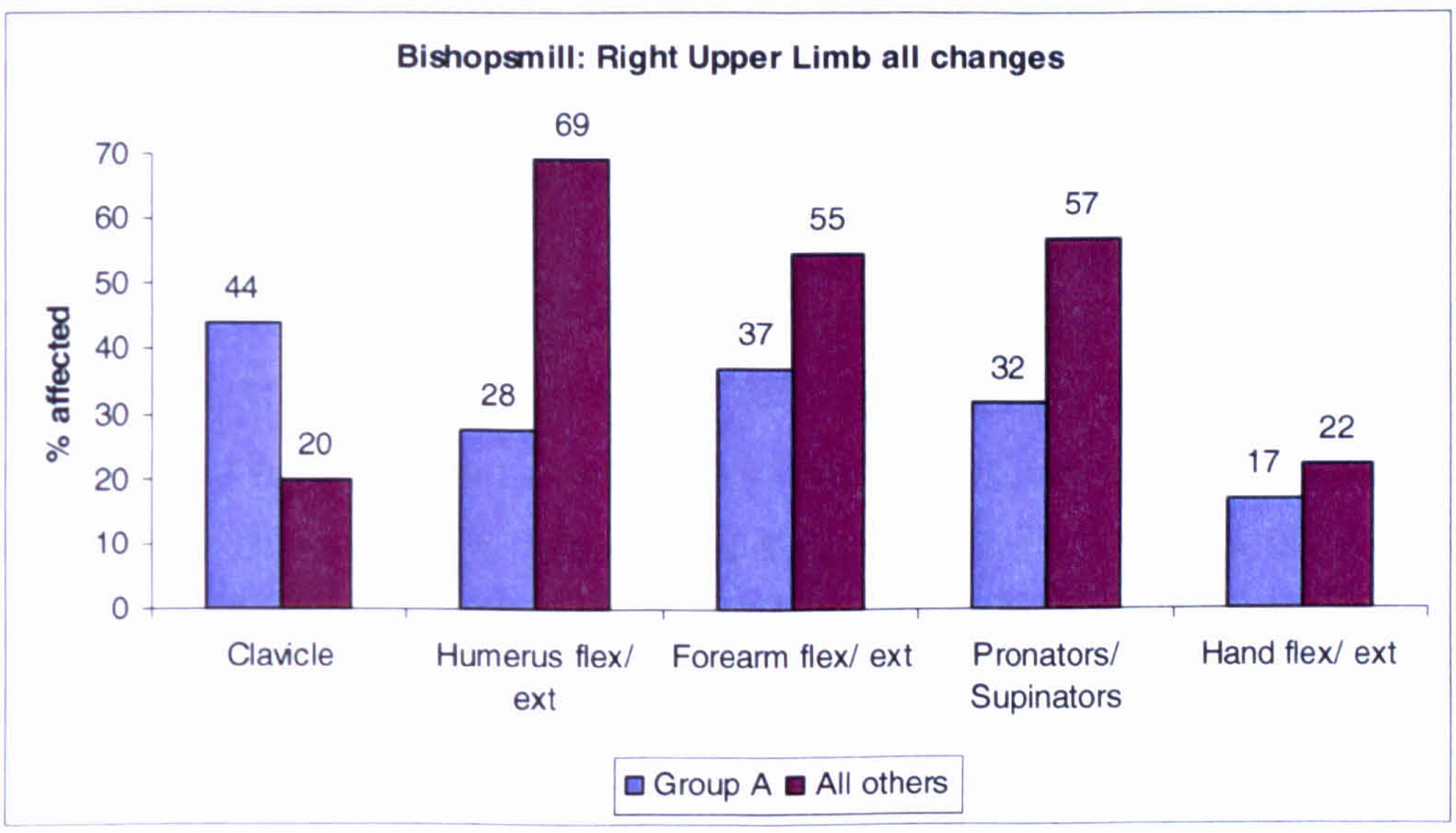


Figure 4.4.4d: The percentage of changes to the entheses on the right side of the upper limb from Group A and all other adults from Norton Bishopsmill

These figures show that, even when compared with all other individuals, the percentage of entheses with changes from Group A was lower than the other groups, except in the clavicles, where the percentage of changes in Group A was significantly higher (chi squared; left side $p= 0.001$, right side $p= <0.001$). The percentage of right humeral flexor and extensor entheses with changes was significantly higher in all other adults than in the individuals from Group A (chi squared p= 0.01). This comparison shows that the difference in the prevalence of enthesopathies was not due to differences in the size of the artefact groups, and was instead the result of another factor. As individuals from all age groups were present in Group A and all other groups, age is not likely to have been a factor in this difference, hence differences in physical activity are a possible cause of this variation.

As the number of individuals with lower limb entheses present for observation from Groups B and C was small, these groups were combined to increase sample size. Other than in the femoral flexors and extensors and the foot flexors, the percentage of enthesopathies was higher on the right side than the left, in all the artefact groups. Group A had the lowest prevalence of enthesopathies in all the entheses, on both sides of the lower limb, and had the lowest percentage of individuals affected. Group D had the highest percentages of gluteus and adductor, quadriceps and femoral flexors entheses affected. Group B and C had the highest percentage of individuals with one or more enthesopathies in the lower limb. As in the upper limb, the results for possible enthesopathies were more homologous between the groups and less clearly lateralised. As with the upper limb, the results for enthesopathies and possible enthesopathies were pooled in order to increase the sample size.

Figures 4.4.4e and 4.4.4f show the percentage of entheses with enthesopathies from the left and right sides of the lower limb from each of the artefact groups. These figures show the higher levels of changes in Group D, although Group B and C individuals also had high frequencies of changes to the right gluteus and adductor entheses. Group A had the lowest prevalence of changes at all entheses, except for the tibio-fibular interosseous membrane, where the percentage affected was lowest in Group D.

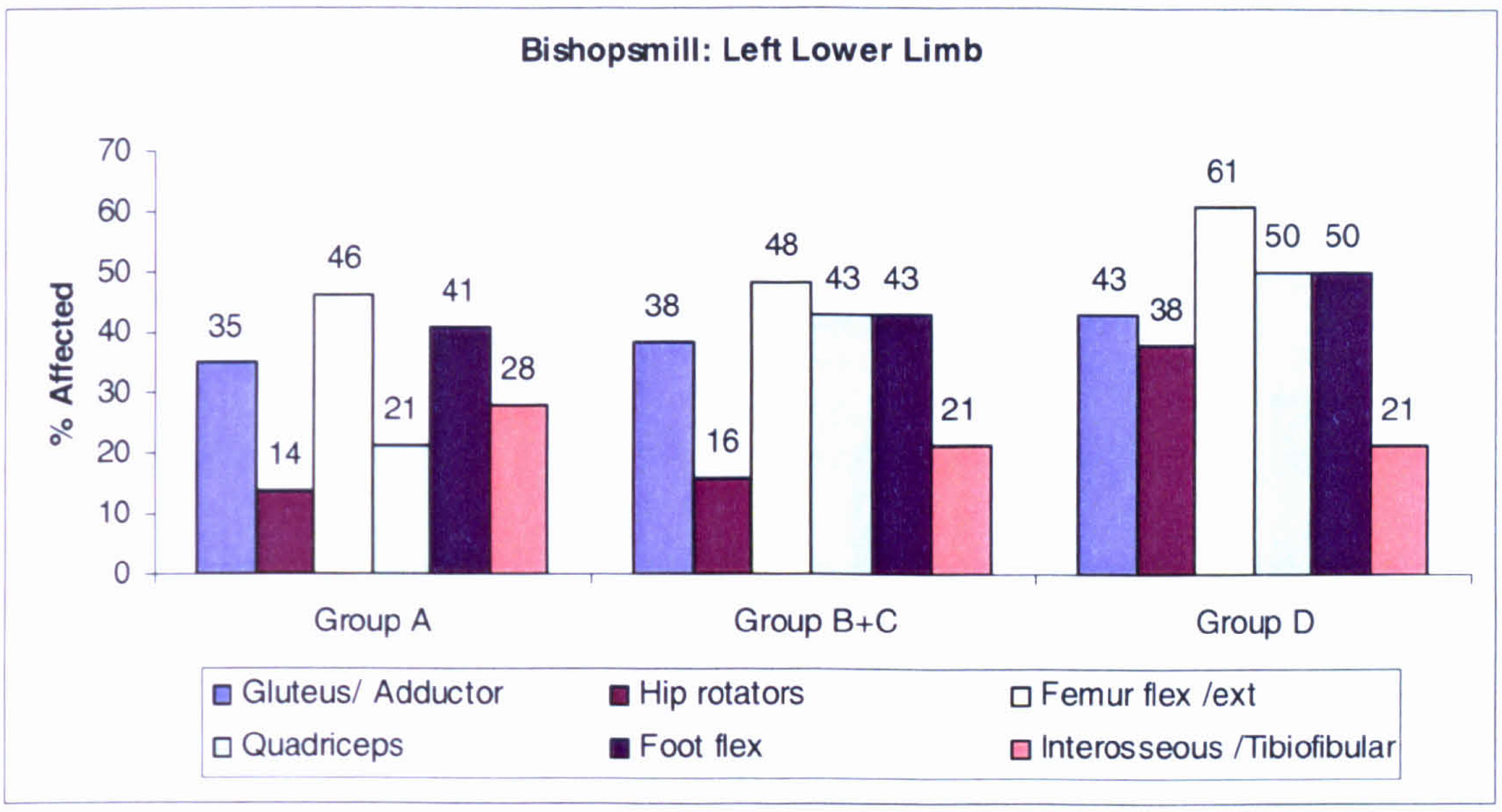


Figure 4.4.4e: The percentages of left lower limb entheses affected in each of the artefact groups from Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – pottery, worked stone or flint, Group D – iron objects or coffin fittings.

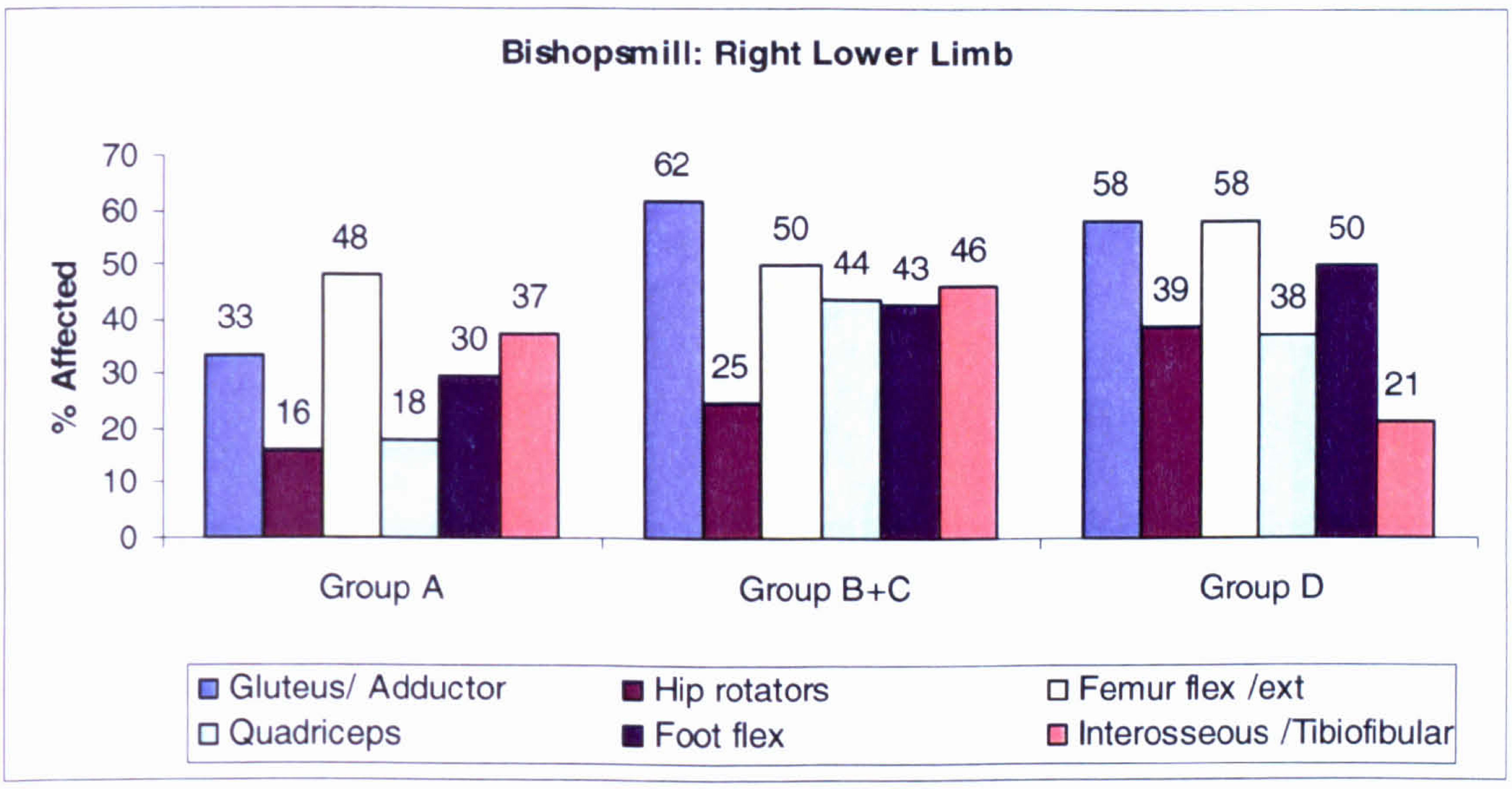


Figure 4.4.4f: The percentages of right lower limb entheses affected in each of the artefact groups from Bishopsmill. Group A – no artefacts, Group B – animal bones or teeth, Group C – pottery, worked stone or flint, Group D – iron objects or coffin fittings.

As with the upper limb, the results from Group A were compared with the results from all other individuals, and Figures 4.4.4g and 4.4.4h show the results of this comparison in the left and right sides of the lower limb. In both sides of the lower limb, Group A had lower levels of changes to the entheses, with the exception of the tibio-fibular interosseous membrane entheses.

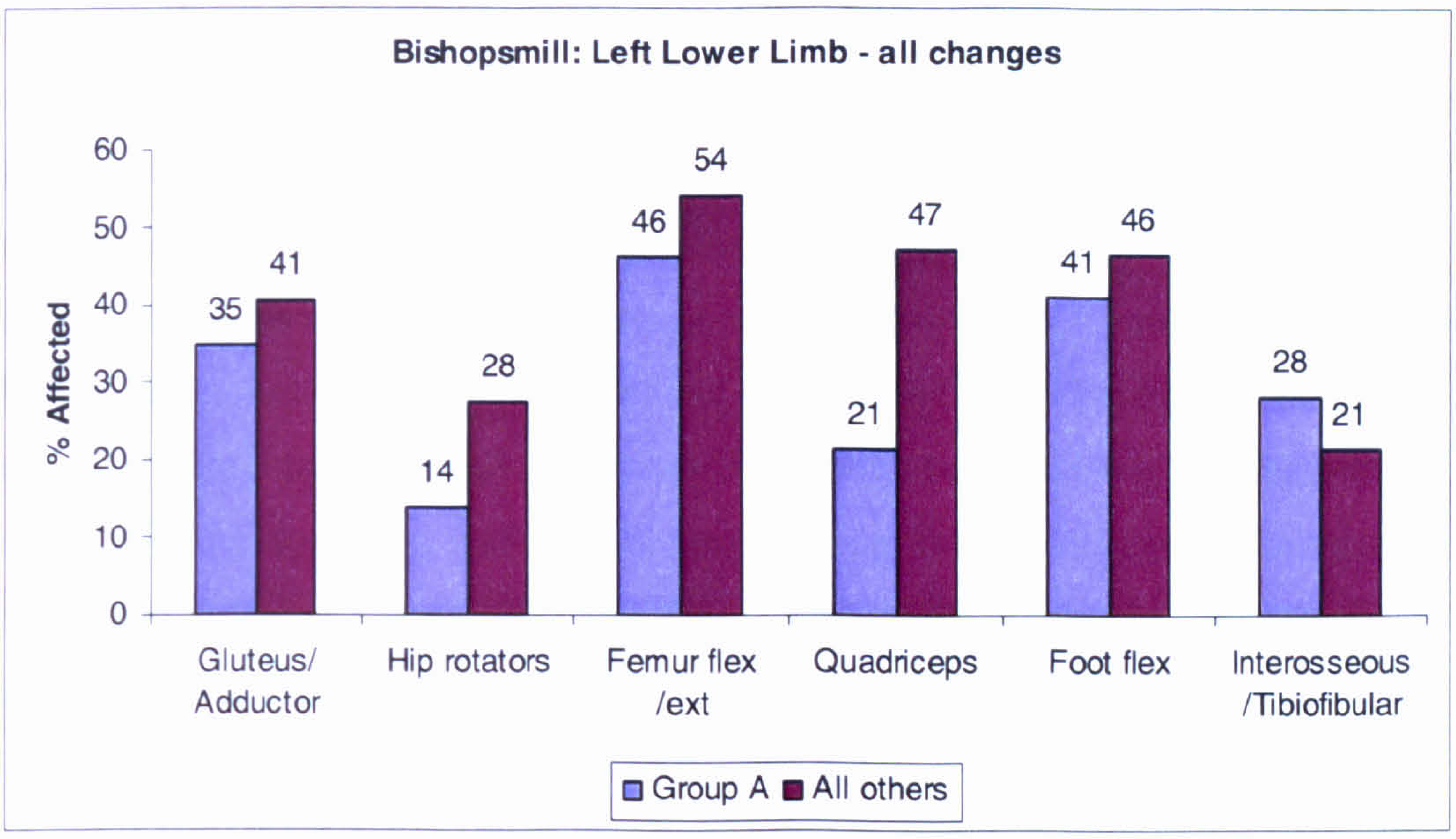


Figure 4.4.4g: The percentages of left lower limb entheses affected from Group A and all other adults.

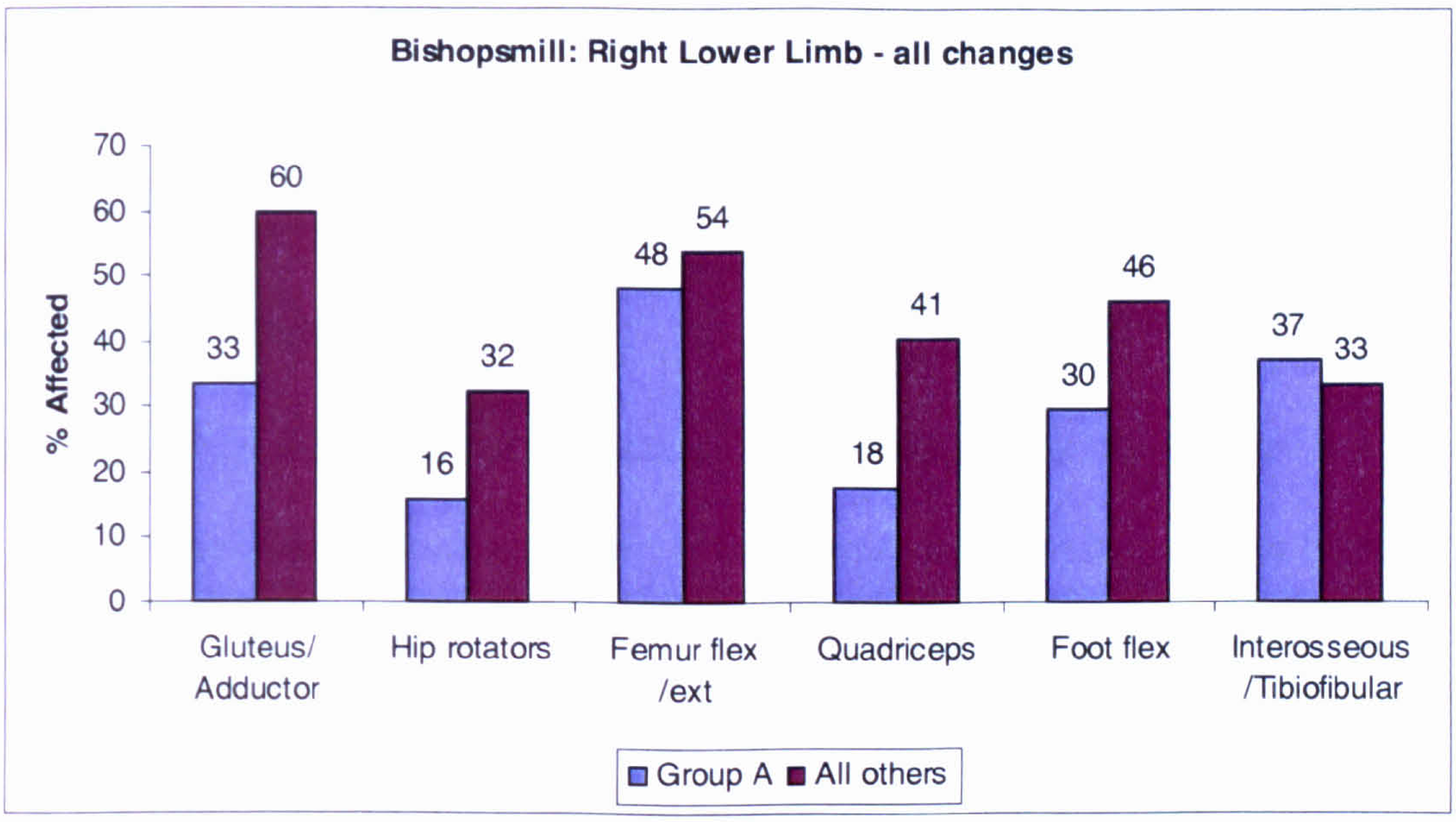


Figure 4.4.4h: The percentages of right lower limb entheses affected from Group A and all other adults.

Furthermore, the percentage of entheses with changes was significantly lower in Group A in the left side of the lower limb, in the femoral flexors and extensors (chi squared p = 0.03), quadriceps p= 0.03) and the foot flexors p=0.05).

These results suggest that the individuals from Norton Bishopsmill that were not buried with any artefacts were less likely to develop changes to the entheses than the individuals that were buried with artefacts. These findings are in marked contrast with the results from the other three sites, where the individuals with the fewest changes were generally those buried with the most complex and varied artefacts. When compared with Norton Mill Lane, the sample that may represent an earlier group from the same population due to the close proximity of the two cemeteries, the results from Bishopsmill are very different. At Mill Lane the individuals from the artefact groups with the fewest grave goods had the highest percentage of enthesopathies in the upper and lower limbs. Furthermore, the enthesis groups that were most frequently affected were different between these two skeletal samples, with the location of entheses affected in Group D from Bishopsmill being more like that seen in Group 1 from Mill Lane. This is particularly noticeable if Figures 4.4.2e and 4.4.2f from Mill Lane are compared with Figures 4.4.4c and 4.4.4d from Bishopsmill, for the upper limb, and for the lower limb, Figures 4.4.2k and 4.4.2l are compared with Figures 4.4.4h and 4.4.4i from Bishopsmill. This suggests that, if these two samples do represent the same population, there may have been a significant shift in the way in which status was acquired or expressed between these two skeletal samples over time, or a difference in the roles and activities undertaken by individuals of high and low social status.

Summary: Enthesopathies

The results of the examination of the entheses were similar to those for osteoarthritis

- The prevalence of enthesopathies varied between the four sites, with the highest frequency of changes seen at Bamburgh and the lowest frequency seen at Norton Bishopsmill

- At all four sites there was a general increase in the prevalence of enthesopathies and possible enthesopathies with increasing age, but this trend was more marked at Castledyke and Bamburgh than at Mill Lane and Bishopsmill.

- Entheses from the right side of the upper limb generally had a higher percentage of changes than the left side, but in the lower limb the patterns of changes were more varied.

- The prevalence of possible enthesopathies between the artefact groups was more homologous than the prevalence of enthesopathies. This suggests that less marked changes to the entheses may be a part of normal human variation, while the more robust changes may be due to other factors.

- At all four sites there were differences in the percentage of entheses affected by changes between the artefact groups, but the differences were most marked in the upper limb.

- At Castledyke South, males buried with weapons (Group 3) had a higher prevalence of enthesopathies in the left humeral flexors, pronators and hand flexors, right forearm flexors, and several of the lower limb entheses. The Group 3 males from Mill Lane had higher levels of enthesopathies in the left forearm flexors, gluteus and adductor and right quadriceps. Group C males from Bamburgh had high frequencies of changes to the right humeral flexors and pronators, femoral flexors and left gluteus and adductor entheses.

- Individuals from Castledyke Group 4 had higher levels of changes in the upper and lower limbs than other females and Bamburgh Group D individuals had higher frequencies of lower limb entheses than all other females, although in this group the upper limb was less affected than all other females, as was also the case for Mill Lane Group 4.

- At Norton Bishopsmill Group A individuals had significantly lower levels of changes in both the upper and lower limbs when compared to all other individuals. This pattern was very different to that seen at the nearby site of Norton Mill Lane.

4.5: Schmorl's Nodes

The following section examines the prevalence of Schmorl's nodes at each of the four sites to identify any differences in frequencies between the artefact groups. The numbers of vertebral surfaces present and affected by Schmorl's nodes from each site are given in Appendix 4.

4.5.1: Castledyke South

From the total sample of 86 individuals, 58 had vertebral surfaces that were sufficiently well preserved to be examined for the presence of Schmorl's nodes, 26 from males, 31 from females and one vertebral column from an individual of unknown sex. Males had an average of 34 surfaces present and an average of 10 Schmorl's nodes; females had an average of 29 surfaces present with an average of seven Schmorl's nodes per vertebral column. Table 4.5.1a shows the number of Schmorl's nodes observed in males and females from the Castledyke South sample, in the cervical, thoracic and lumbar regions of the vertebral column, and the percentage of surfaces affected in each region of the vertebral column that were affected by Schmorl's nodes. The number and percentage of individuals is also given.

	Cervical		Thoracic		Lumbar		Sk
Sex	**Superior**	**Inferior**	**Superior**	**Inferior**	**Superior**	**Inferior**	affected
Female	1 (2)	3 (5)	46 (19)	103 (41)	32 (20)	29 (21)	27 (87)
Male	0 (0)	2 (2)	70 (28)	112 (44)	43 (39)	32 (32)	22 (85)

Table 4.5.1a: The number of Schmorl's nodes observed in the Castledyke South sample according to sex and location in the vertebral column. The percentage of surfaces affected in each region of the vertebral column is shown in brackets. The total number and percentage of individuals affected by Schmorl's nodes is also given.

In both males and females, the percentage of Schmorl's nodes was greatest in the thoracic vertebrae, and lowest in the cervical vertebrae. In the cervical and thoracic regions, in both males and females, the percentage of Schmorl's nodes was greater in the inferior surfaces of the vertebrae, but in the lumbar vertebrae the superior surface was more frequently affected in males. There were significantly more Schmorl's nodes observed in males than in females (chi squared p=0.01), but when the average number of Schmorl's nodes was compared between males and females, the difference was not significant

(ANOVA p=0.3). Overall, the percentage of inferior surfaces (32%) with Schmorl's nodes was higher than the percentage of superior surfaces affected (22%) and this difference was statistically significant (chi squared p=0.01).

i) Schmorl's nodes, Age and Sex

Table 4.5.1b shows the percentage and number (in brackets) of vertebral surfaces with Schmorl's nodes, from males and females across the whole vertebral column, the average number of Schmorl's nodes in each of the age groups and the number and percentage of individuals affected. In females the percentage of Schmorl's nodes was greatest in the Middle age group and lowest in the Young/Middle and Young age groups. In males the percentage of Schmorl's nodes was greatest in the Young Middle age group.

Age Group	Female SN	Male SN	Average SN	Sk affected
Young	18 (35)	26 (81)	7	15 (83)
Young/ Middle	25 (30)	43 (32)	8	6 (75)
Middle	31 (67)	40 (62)	9	12 (86)
Older	23 (82)	25 (84)	9	17 (89)

Table 4.5.1b: Number and percent of vertebral surfaces observed with Schmorl's nodes and the average number of surfaces affected in each of the age groups The number and percentage (in brackets) of individuals affected is also given: Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

The average number of vertebral surfaces affected by Schmorl's nodes was very similar between the age groups and the variation was not significant (ANOVA p=0.3), and the number of individuals affected was also similar in the age groups, suggesting that age was not an important factor in the development of Schmorl's nodes.

ii) Schmorl's Nodes and Status

Table 4.5.1c shows the percentage and number of the total possible surfaces with Schmorl's nodes, and the average number of surfaces that were affected in each artefact group, in males and females across the whole vertebral column. The percentage and number of individuals with Schmorl's nodes is also given.

Artefact Group	% SN	Number SN	Average SN	Sk affected
Group 1	31	170	9	83 (15)
Group 2	25	167	8	82 (18)
Group 3	41	74	15	100 (5)
Group 4	17	64	5	92 (12)

Table 4.5.1c: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in individuals from each of the artefact groups. The percentage and number (in brackets) of individuals with Schmorl's nodes is also given. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Both the percentage of vertebral surfaces affected and the average number affected were highest in Group 3 and lowest in Group 4. However, the percentage of individuals affected in each of the artefact groups was similar. This suggests that the average number of surfaces affected is a better indication of the differences in involvement of the vertebral surfaces between the artefact groups. Table 4.5.1d shows the distribution of Schmorl's nodes in the thoracic and lumbar regions of the vertebral column in each of the artefact groups. As the number of cervical vertebrae affected in each group was small (an average of 0.1 Schmorl's nodes in each artefact group) this region was not compared between the artefact groups.

Artefact	Thoracic			Lumbar		
Group	% SN	No SN	Av SN	% SN	No SN	Av SN
Group 1	35	108	6	39	61	3
Group 2	31	117	5	25	47	2
Group 3	45	51	10	55	22	4
Group 4	28	57	4	5	6	1

Table 4.5.1d: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in the thoracic and lumbar vertebrae from individuals from each of the artefact groups. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.5.1a shows the average number of surfaces affected in each artefact group in the whole vertebral column and the thoracic and lumbar vertebrae. The error bars show the standard error of the mean (SEM), which gives an indication of how representative the average is of the whole sample.

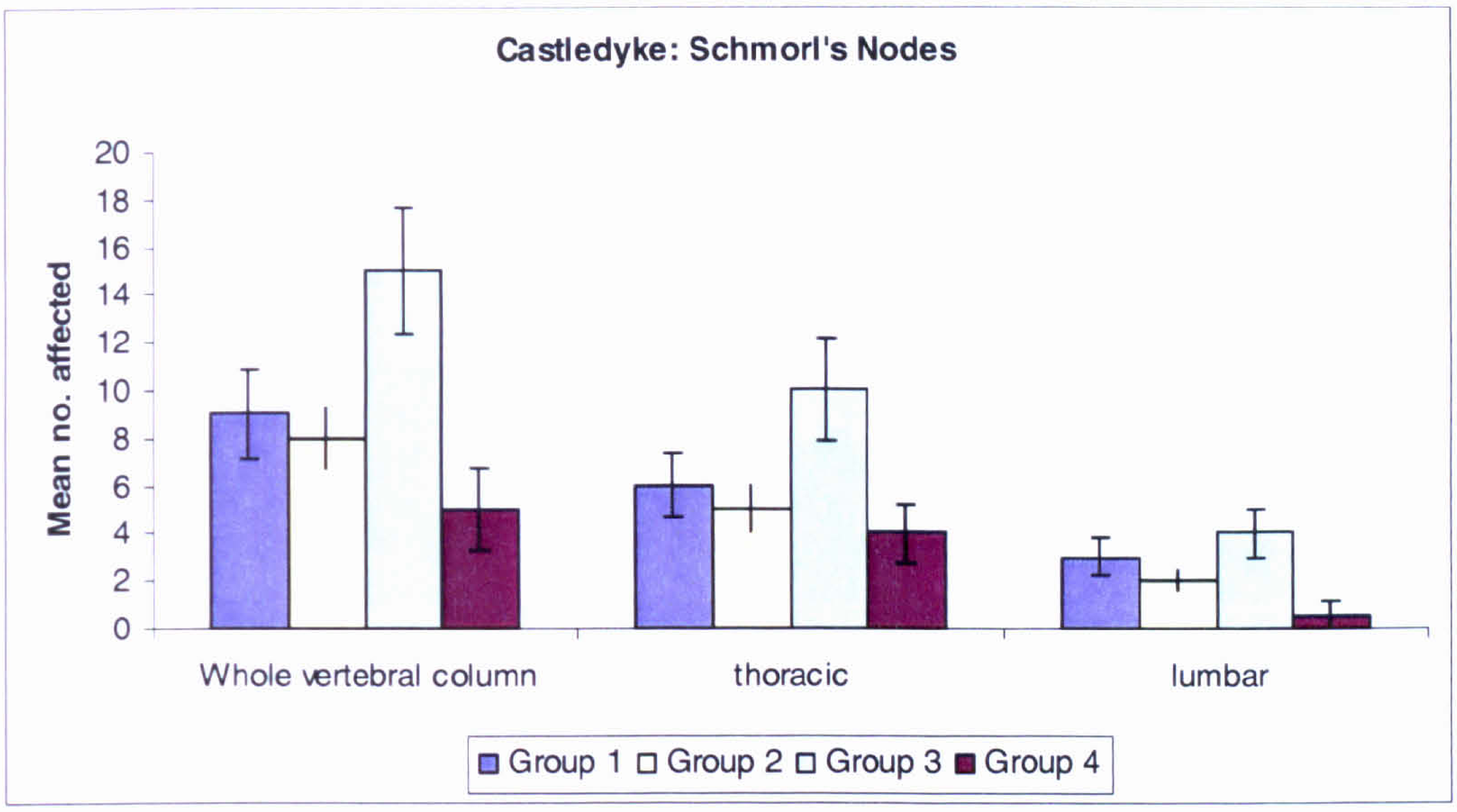


Figure 4.5.1a: The average number of Schmorl's nodes in each of the artefact groups at Castledyke South. Error bars - +/- SEM. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

This figure shows that Group 3 had on average the highest number of Schmorl's nodes in the whole vertebral column, and in the thoracic and lumbar regions. Group 4 had the lowest average number of Schmorl's nodes in all regions. In order to exclude the possibility that differences in sex were responsible for the variations in prevalence of Schmorl's nodes, Group 3 was compared with other males (Figure 4.5.1b) and Group 4 was compared with all other females (Figure 4.5.1c). Figure 4.5.1b shows that even when compared with all other males, the average number of Schmorl's nodes was higher in Group 3 in the whole vertebral column and in both the thoracic and lumbar vertebrae, although these differences were not statistically significant (ANOVA; whole vertebral column $p = 0.2$, thoracic $p=0.1$, lumbar $p= 0.2$)

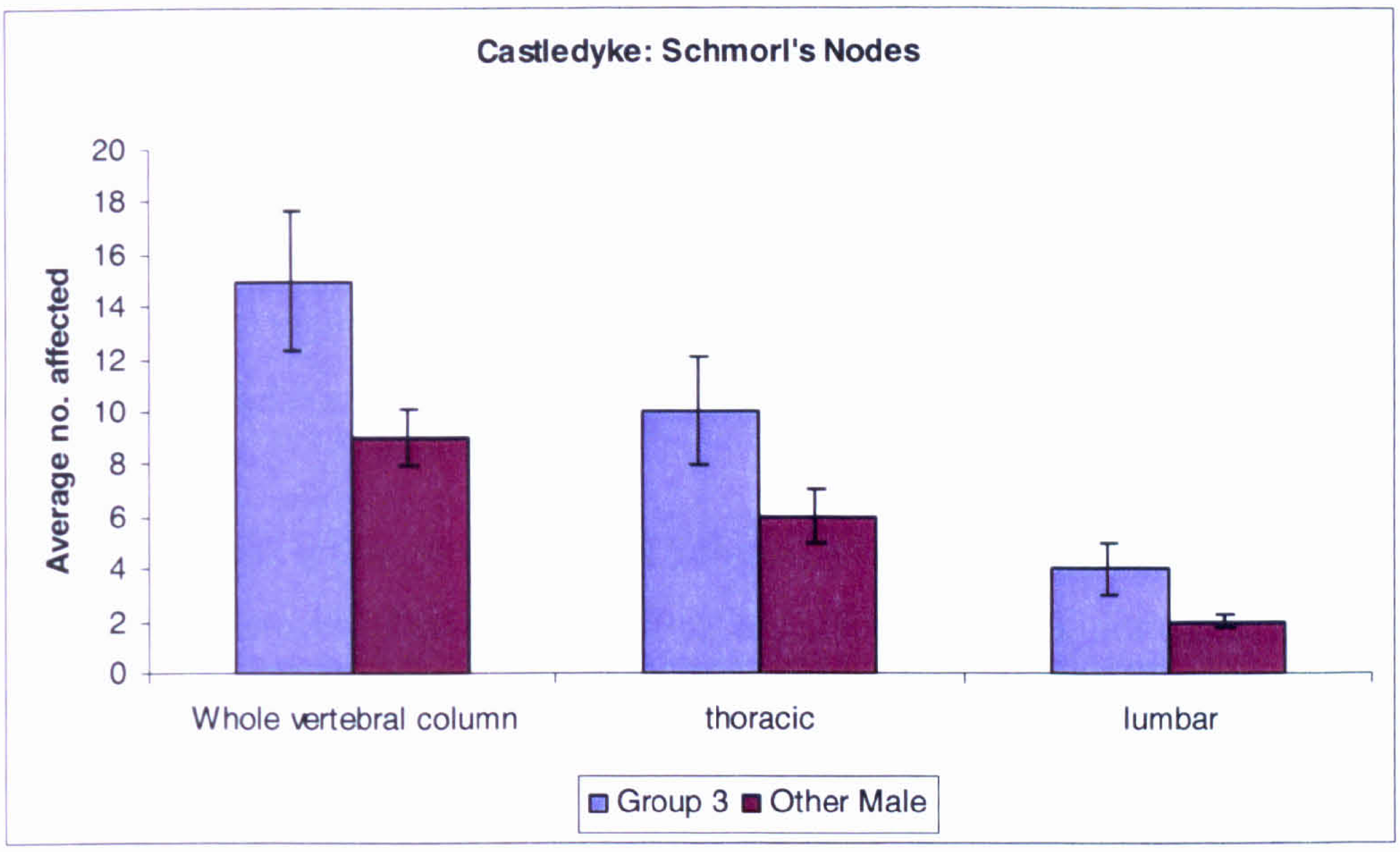


Figure 4.5.1b: The average number of Schmorl's nodes from Group 3 and all other males from Castledyke South. Error bars - +/- SEM.

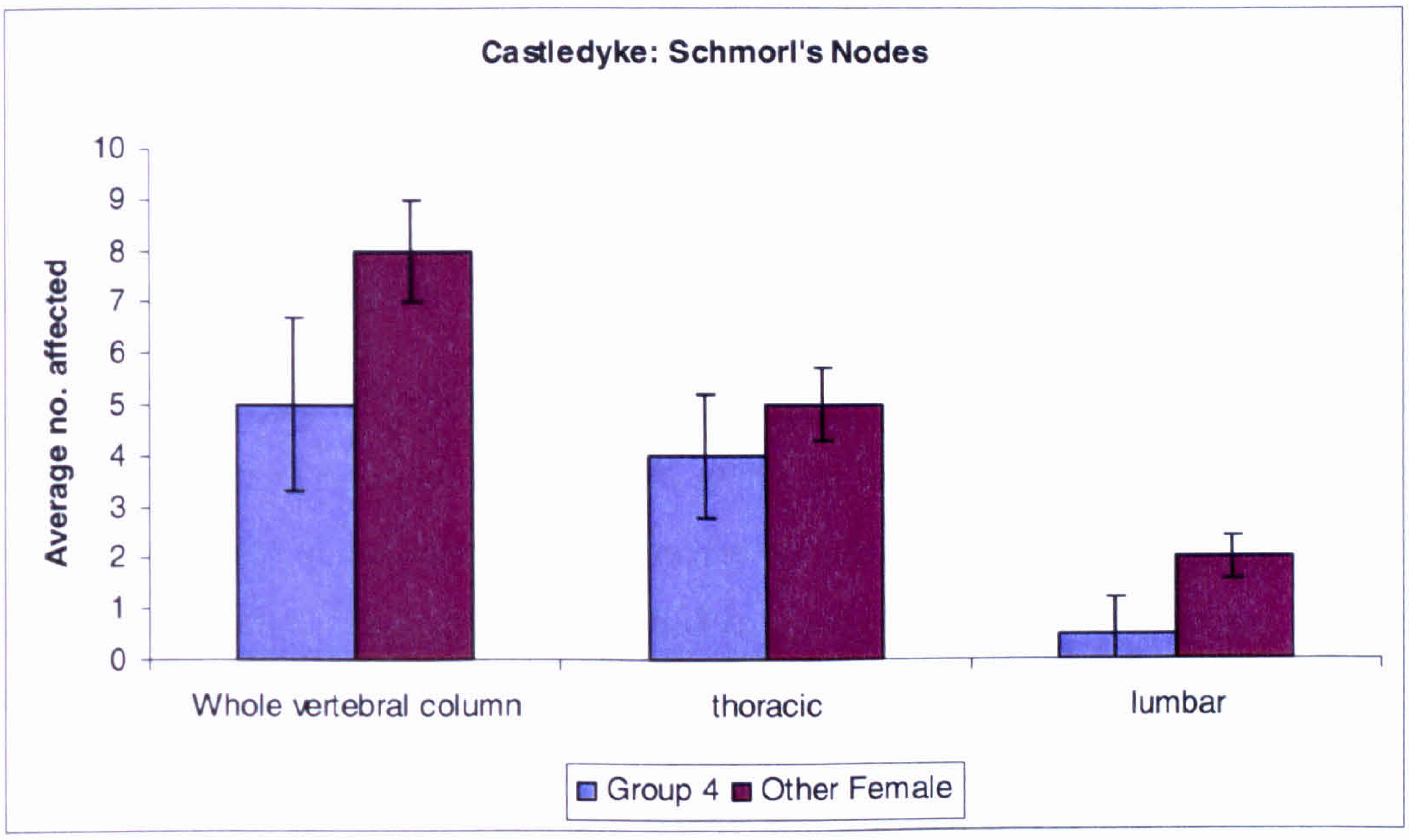


Figure 4.5.1c: The average number of Schmorl's nodes from Group 4 and all other females from Castledyke South. Error bars - +/- SEM.

Figure 4.5.1c shows that Group 4 females had a lower average number of Schmorl's nodes in all regions of the vertebral column, when compared with all other females. In the lumbar vertebrae the number of Schmorl's nodes was significantly lower than in all other females (ANOVA p= 0.02)

Figures showing the location of Schmorl's nodes in the vertebral column in each of the four artefact groups are given in Appendix 4.1. In Group 1, all regions of the vertebral column showed Schmorl's nodes, with the highest percentage of surfaces affected with Schmorl's nodes observed in the inferior surface of the T11 vertebra, and high percentages seen in the lower thoracic and lumbar vertebrae. Few cervical and upper thoracic surfaces were affected.

In Group 2, the peak in the percentages of Schmorl's nodes was seen around T7 and T9, with greater percentages of inferior surfaces being affected. Again, few of the cervical vertebral surfaces were affected. In Group 3 100% of both surfaces from T8 and the superior surface of T12 were affected by Schmorl's nodes, with a high percentage of surfaces between T6 and L4 being affected. In Group 4, the surfaces affected by Schmorl's nodes were clustered in the region between T6 and L1, with only relatively low percentages of C2 and L4 showing Schmorl's nodes outside of this region of the vertebral column. This suggests that there were differences in the locations and frequencies of Schmorl's nodes in the different artefact groups from Castledyke South.

4.5.2: Norton Mill Lane

From the total sample of 51 individuals, 37 individuals had vertebral columns that could be examined for the presences of Schmorl's nodes, of which 23 were male, 13 were female and one was of unknown sex. Males had an average of 21 surfaces present and an average of five Schmorl's nodes; females had an average of 29 surfaces present and also had an average of five Schmorl's nodes per vertebral column.

Table 4.5.2a shows the number of Schmorl's nodes observed in males and females from the Norton Mill Lane sample, in the cervical, thoracic and lumbar regions of the vertebral column, and the percentage of surfaces affected in each region of the vertebral column that were affected by Schmorl's nodes. The one individual of unknown sex was excluded from these results. The number and percentage of individuals with Schmorl's nodes is also given.

Sex	Cervical Superior	Cervical Inferior	Thoracic Superior	Thoracic Inferior	Lumbar Superior	Lumbar Inferior	Sk affected
Female	3 (6)	4 (10)	10 (10)	25 (24)	11 (21)	10 (22)	8 (62)
Male	3 (6)	8 (15)	29 (23)	34 (28)	16 (22)	17 (30)	17 (74)

Table 4.5.2a: The number of Schmorl's nodes observed in the Mill Lane sample according to sex and location in the vertebral column. The percentage of surfaces affected in each region of the vertebral column is shown in brackets. The number and percentage of individuals affected is also given.

This Table shows that in both males and females, the highest percentage of Schmorl's nodes was seen in the thoracic vertebrae, in the inferior surfaces, and was lowest in the superior surfaces of the cervical vertebrae where very few surfaces were affected. The percentage of Schmorl's nodes was highest in males in all regions of the vertebral column, except in the cervical vertebrae where the percentage of superior surfaces affected was the same in males and females. The percentage of males with Schmorl's nodes was also higher than the percentage of females affected However, when the average number of Schmorl's nodes was compared between males and females, the difference was not significant (ANOVA p=0.7). Overall, the percentage of inferior surfaces with Schmorl's nodes (23%) was significantly higher than the percentage of superior surfaces affected (16%) (chi squared p=<0.01)

i) Schmorl's nodes, Age and Sex

Table 4.5.1b shows the percentage and number (in brackets) of vertebral surfaces with Schmorl's nodes, from males and females across the whole vertebral column, the average number of Schmorl's nodes and the number and percentage of individuals affected in each of the age groups. In females the Middle and Older age groups had the highest percentage of surfaces with Schmorl's nodes, and in males the Middle aged group was the most frequently affected. Although there was some variation in the average number of surfaces affected between the age groups, this variation was not significant (ANOVA p= 0.4).

Age Group	Female SN	Male SN	Average SN	Sk affected
Young	12 (25)	8 (11)	2	54 (7)
Young/ Middle	29 (22)	17 (19)	5	88 (7)
Middle	14 (13)	40 (55)	7	70 (4)
Older	29 (2)	17 (8)	3	100 (4)

Table 4.5.2b: Number and percent of vertebral surfaces observed with Schmorl's nodes and the average number of surfaces affected, and the number and percentage of individuals with Schmorl's nodes in each of the age groups: Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

The percentage of individuals affected was highest in the Older adults, but the average number of vertebral surfaces affected in this group was small. There was no definite increase in the percentage of individuals affected with increasing age.

In the Young adults, none of the cervical vertebrae were affected by Schmorl's nodes and, in the upper thoracic vertebrae, only the inferior surface of T11 was affected. The highest percentage of surfaces affected in this age group was seen in the 12th thoracic vertebra. In the Young/Middle aged adults, the inferior surfaces of the 4th and 6th cervical vertebrae were affected; there was a peak in the percentage of Schmorl's nodes in the region of the 8th thoracic vertebra, and high levels of Schmorl's nodes through to the lower thoracic and lumbar vertebrae. In the Middle aged adults, the cervical vertebrae were more affected than in the younger groups, with C2 to C5 all affected. Schmorl's nodes affected all vertebral surfaces from the inferior surface of T3 to the inferior surface of L5, with the highest levels being seen in the inferior surfaces of T3, T8, T9, T11 and the superior surfaces of T12 and L1. In the Older adults, the preservation of the vertebral columns was poor, but where vertebral surfaces were preserved, the levels of Schmorl's nodes were high. As there were only two individuals from this age group, it is impossible to be sure that these results are representative of the pattern of Schmorl's nodes in Older individuals. Overall, the lowest levels of Schmorl's nodes were seen in the Young age group.

ii) Schmorl's Nodes and Status

Table 4.5.2c shows the percentage and number of surfaces with Schmorl's nodes, the average number of surfaces affected and the percentage and number of individuals affected in each of the artefact groups.

Artefact Group	% SN	Number SN	Average SN	Sk affected
Group 1	18	18	5	75 (3)
Group 2	20	62	5	83 (10)
Group 3	37	54	8	71 (5)
Group 4	13	41	3	57 (8)

Table 4.5.2c: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in individuals from each of the artefact groups. The percentage and number (in brackets) of individuals with Schmorl's nodes is also given. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

The percentage of surfaces with Schmorl's nodes and the average number of Schmorl's nodes was highest in Group 3, but Group 2 had the highest percentage of individuals affected. Table 4.5.2d shows the distribution of Schmorl's nodes in the thoracic and lumbar regions of the vertebral column in each of the artefact groups. As the number of cervical vertebrae affected in each group was small (an average of less than 0.1 Schmorl's nodes in each artefact group) this region was not compared.

Artefact	Thoracic			Lumbar		
Group	% SN	No SN	Av SN	% SN	No SN	Av SN
Group 1	12	6	2	38	9	2
Group 2	24	37	3	25	22	2
Group 3	45	38	5	28	11	2
Group 4	12	20	1	18	15	1

Table 4.5.2d: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in the thoracic and lumbar vertebrae from individuals from each of the artefact groups. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Group 3 had the highest percentage of Schmorl's nodes and the highest average number of surfaces affected in the thoracic region of the vertebral column, but in the lumbar region the results were more homologous. As Group 1 consisted of vertebral surfaces from only four individuals it is likely that the results for this group are not representative. Group 4 was least affected by Schmorl's nodes in both regions. In comparison with Castledyke South, the percentage of surfaces affected in each artefact group was lower, as was the average number of surfaces affected, although the patterns of Schmorl's nodes between the artefact groups at the two sites were similar.

Figure 4.5.2a shows the average number of surfaces affected in each artefact group in the whole vertebral column and the thoracic and lumbar vertebrae. The error bars show the standard error of the mean (SEM), which gives an indication of how representative the average is of the whole sample.

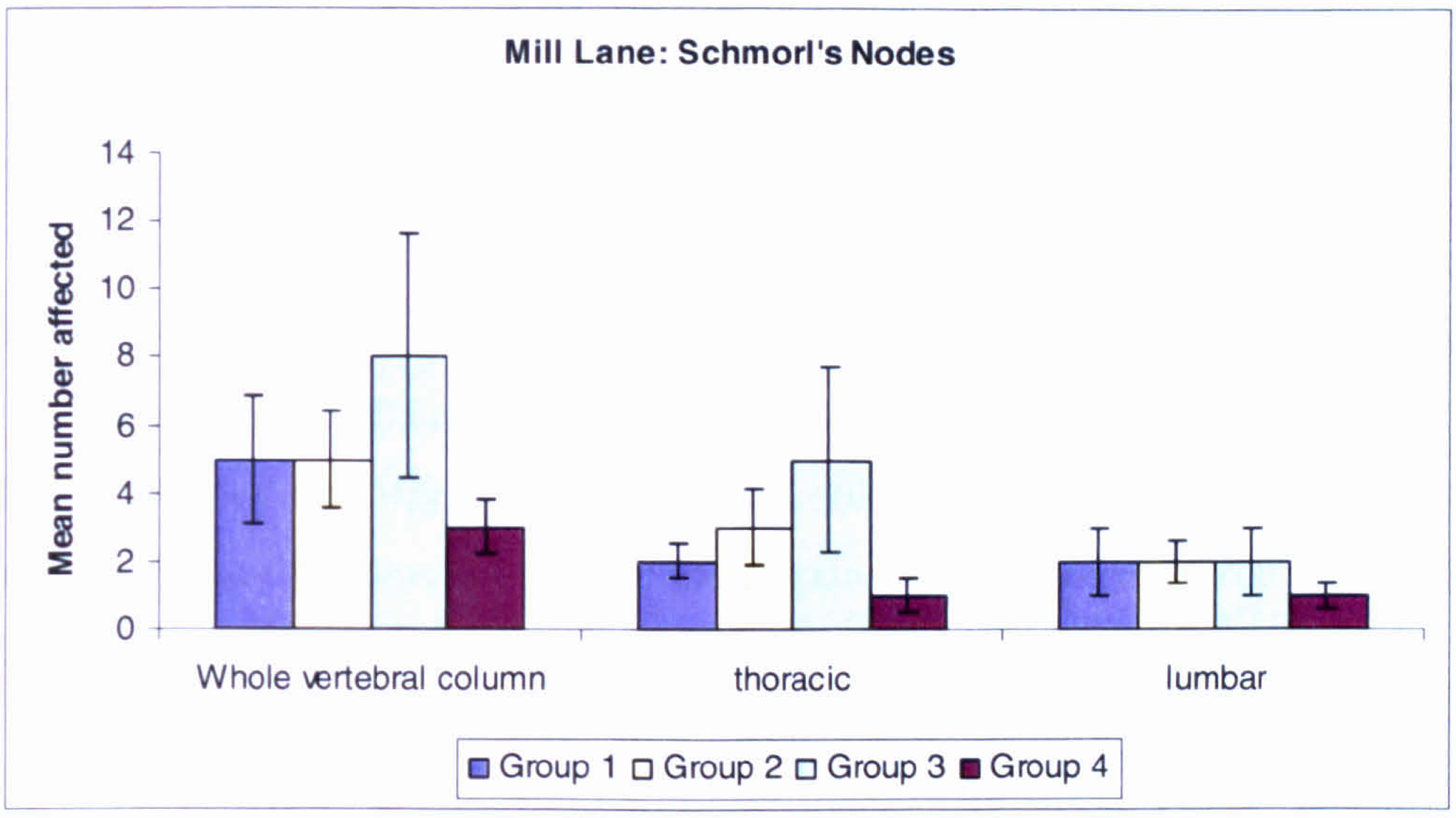


Figure 4.5.2a: The average number of Schmorl's nodes in each of the artefact groups at Norton Mill Lane. Error bars - +/- SEM. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

This figure highlights the difference in the average number of vertebral surfaces affected in Group 3 and Group 4, in comparison with the other two artefact groups in the whole vertebral column and in the thoracic vertebrae. The similarity in the average number of lumbar surfaces affected in Groups 1, 2 and 3 is also clear. Figures 4.5.2b and 4.5.2c compare the results from Group 3 with all other males and Group 3 with all other individuals. Figure 4.5.2b shows that, when compared with all other males, the mean number of vertebral surfaces affected in Group 3 males was higher than that seen in all other males, in all regions of the vertebral column. In the thoracic region, the mean number of Schmorl's nodes was significantly higher in Group 3 (ANOVA p= 0.05).

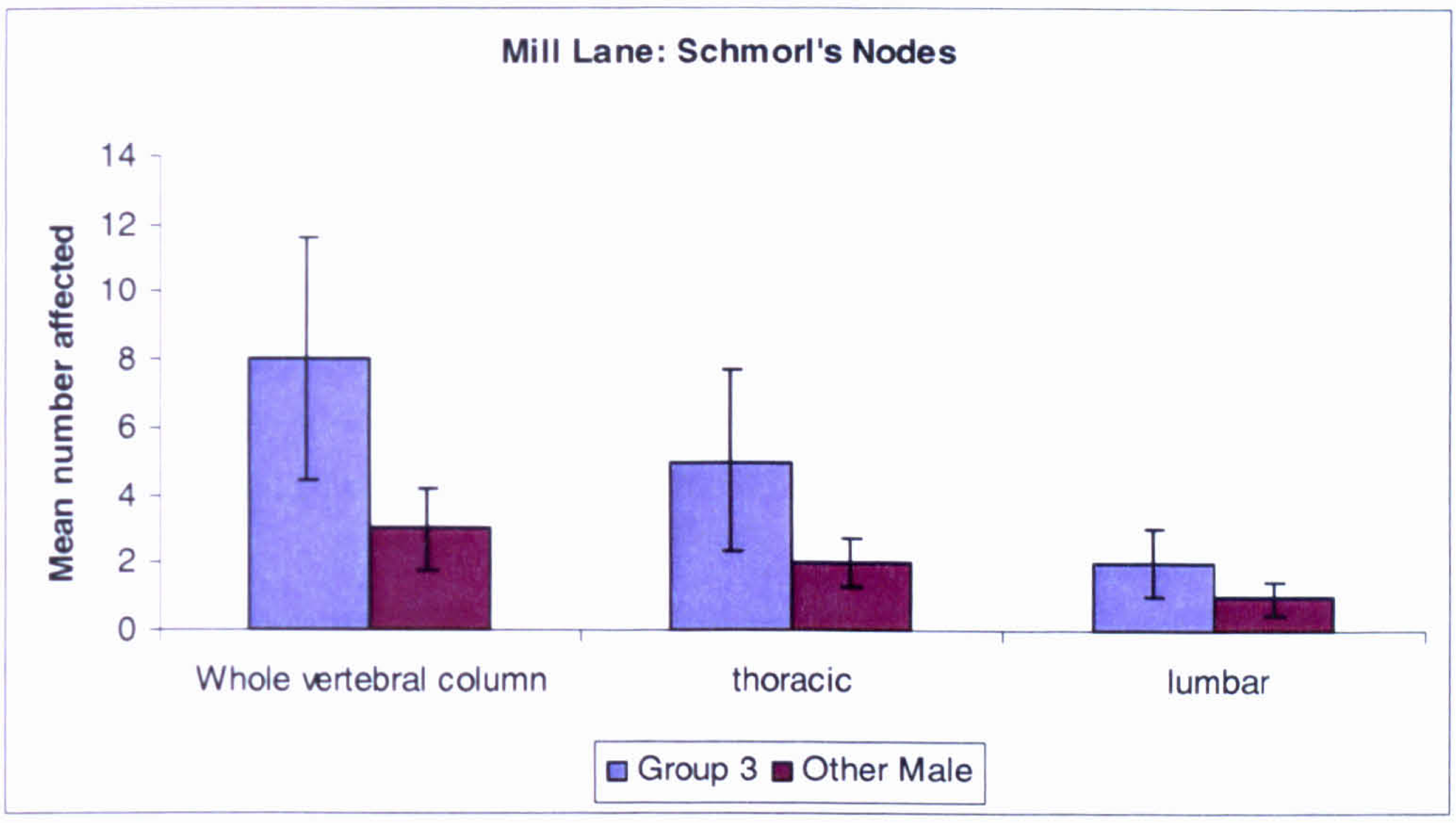


Figure 4.5.2b: The average number of Schmorl's nodes in Group 3 and all other males at Norton Mill Lane. Error bars - +/- SEM.

Figure 4.5.2c compares the mean number of surfaces affected between Group 4 and all other individuals from Mill Lane. Unlike Group 4 at Castledyke, although the majority of individuals in Group 4 at Mill Lane were females, (nine individuals) there were also five males in this group, so it was not realistic to compare the results from Group 4 with females alone.

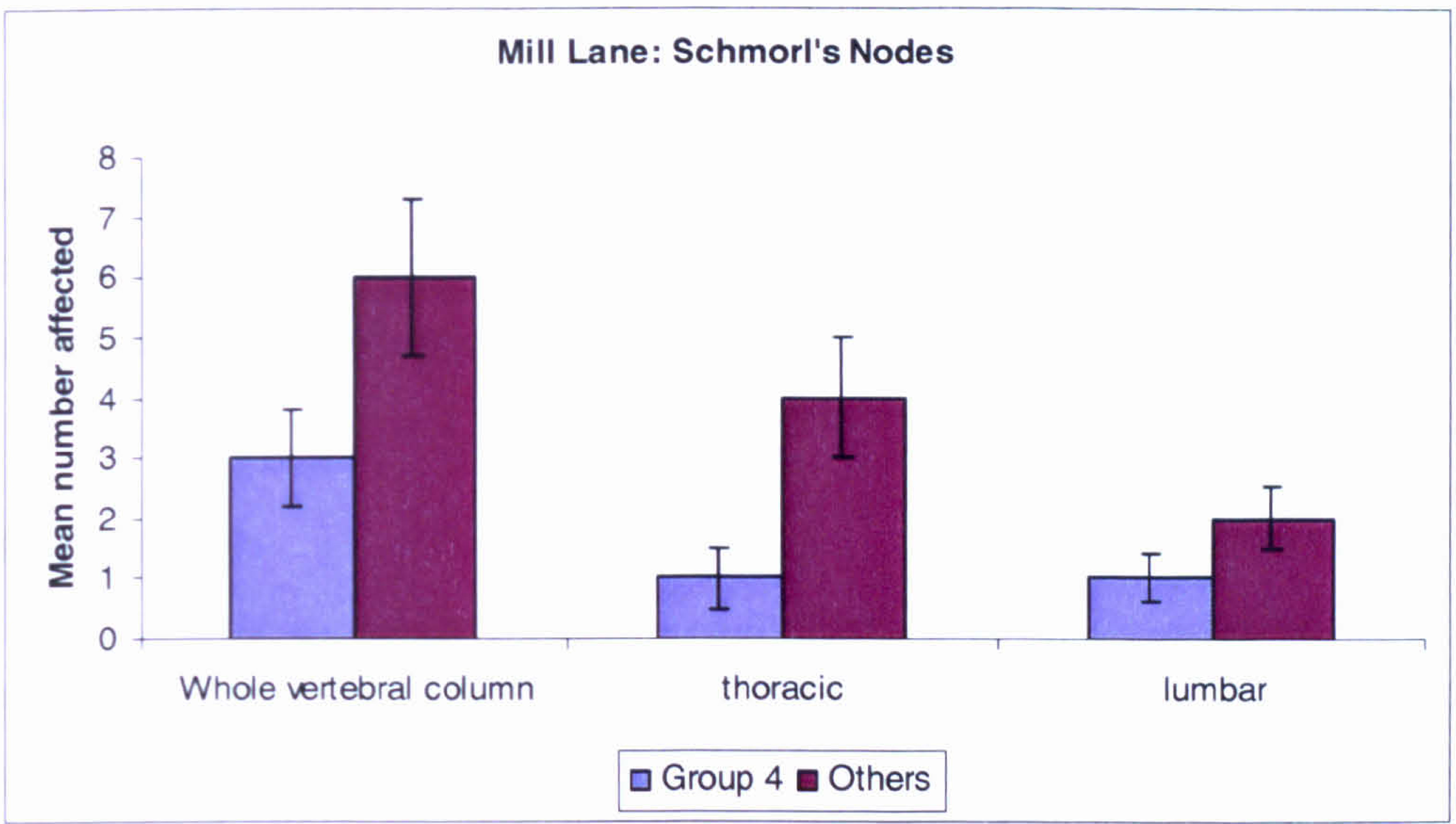


Figure 4.5.2c: The average number of Schmorl's nodes in Group 4 and all other individuals at Norton Mill Lane. Error bars - +/- SEM.

From Figure 4.5.2c it is clear that the mean number of surfaces affected was much lower in Group 4 than in all other individuals, particularly in the thoracic vertebrae, although this difference was not significant (ANOVA p= 0.1)

Figures showing the location of Schmorl's nodes in the vertebral column in each of the four artefact groups are given in Appendix 4.2. In Group 1, all regions of the vertebral column were affected by Schmorl's nodes, but the region between C6 and T6 had no Schmorl's nodes. The highest percentages of vertebral surfaces affected by Schmorl's nodes were seen in the inferior surface of T7 and the superior surface of L4.

In Group 2, again all regions of the vertebral column were affected, but in the cervical vertebrae only the lower region, C4 to C6, was affected. Few of the upper thoracic vertebrae were affected, but from T8 to L3 the percentage of surfaces affected was much higher. In Group 3 almost all the vertebrae were affected by Schmorl's nodes, with only C3, C4, T1 and S1 being entirely unaffected. The highest percentage of Schmorl's nodes was seen in the inferior surface of C2, although as this was only a single surface this is not representative of the group as a whole. There was also a peak in the percentage of affected surfaces around T8. Overall, the percentage of surfaces affected by Schmorl's nodes in Group 3 was higher than in all the other artefact groups. In Group 4, few of the vertebral surfaces were affected by Schmorl's nodes, but the cervical region was more affected than in the other artefact groups, although the levels of Schmorl's nodes were low in the other regions of the vertebral column. The highest number of surfaces with Schmorl's nodes was seen in T12. Clearly there was considerable variation in the number and location of Schmorl's nodes between the artefact groups at Mill Lane, variation which may be the result of differences in physical activity.

4.5.3: Bamburgh

From the total sample of 40 individuals, 32 individuals had vertebral surfaces that were sufficiently well preserved for Schmorl's nodes to be identified, 19 vertebral columns from males and 13 from females. Males had on average 34 surfaces present and an average of 11 Schmorl's nodes. Females had an average of 39 surfaces present, with a slightly lower average of seven Schmorl's nodes per individual.

Table 4.5.3a shows the number of Schmorl's nodes observed in males and females from the Bamburgh sample, in the cervical, thoracic and lumbar regions of the vertebral column, and the percentage of surfaces observed in each region of the vertebral column that were affected by Schmorl's nodes, shown in brackets. The number and percentage of individuals affected is also given.

	Cervical		Thoracic		Lumbar		Sk
Sex	Superior	Inferior	Superior	Inferior	Superior	Inferior	affected
Female	2 (4)	2 (4)	14 (11)	38 (28)	15 (20)	14 (22)	11 (85)
Male	4 (6)	5 (7)	61 (34)	83 (46)	30 (36)	22 (31)	15 (79)

Table 4.5.3a: Schmorl's nodes observed in the Bamburgh sample according to sex and location in the vertebral column. The percentage of surfaces affected in each region of the vertebral column is shown in brackets. The number and percentage of individuals affected is also given.

The cervical vertebrae were the least affected by Schmorl's nodes of all three regions of the vertebral column, in both males and females. The largest numbers of Schmorl's nodes were seen in the thoracic vertebrae; and males had more Schmorl's nodes than females, in all regions of the vertebral column. However, the percentage of males with Schmorl's nodes was higher than the percentage of females.

In the cervical vertebra, the numbers of Schmorl's nodes in the superior and inferior surfaces of the vertebrae were very similar, while in the thoracic vertebrae, the inferior surface was more commonly affected, and in the lumbar vertebrae there were more Schmorl's nodes in the superior surfaces. The number of Schmorl's nodes was significantly higher in males than in females (chi squared p=0.01), but the average number of surfaces affected was not significantly different between males and females (ANOVA p= 0.1) Overall, there were significantly more Schmorl's nodes on inferior surfaces (164) than on the superior surfaces of the vertebrae (126) (chi squared p = 0.02).

i) Schmorl's nodes, Age and Sex

Table 4.5.3b shows the percentage and number (in brackets) of vertebral surfaces with Schmorl's nodes, from males and females across the whole vertebral column, and the average number of Schmorl's nodes in each of the age groups. The percentage and number of individuals with Schmorl's nodes in each age group is also given. As the number of individuals from the young and Young/Middle age groups was small, these groups were combined.

Age Group	Female SN	Male SN	Average SN	Sk affected
Younger	20 (18)	24 (43)	8	63 (5)
Middle	13 (26)	29 (34)	7	78 (7)
Older	19 (41)	37 (128)	11	93 (14)

Table 4.5.1b: Number and percent of vertebral surfaces observed with Schmorl's nodes and the average number of surfaces affected in each of the age groups: Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

Amongst the males, Schmorl's nodes were most frequent in older individuals (chi squared p= 0.01), but there was no significant increase in involvement with age amongst females. The percentage of individuals affected also increased with age. However, when the average number of Schmorl's nodes in each age group was compared, there was no significant variation in the number of surfaces affected (ANOVA p= 0.3). In the Young and Young/middle aged individuals, Schmorl's nodes were mostly observed in the mid and lower thoracic and upper lumbar regions of the vertebral column. Of the 47 vertebral surfaces in the vertebral column that were examined for changes in this group, 24 of these surfaces were not affected in any of the individuals. In the Middle aged adults, the lower cervical, thoracic and lumbar regions were all affected by Schmorl's nodes, with 19 surfaces unaffected from the total of 46 (no inferior surfaces from the first sacral vertebra were observed in this age group, as all sacra were fully fused). In the Older adult group, all regions of the vertebral column were affected, with only seven vertebral surfaces unaffected in any individuals.

ii) Schmorl's Nodes and Status

Table 4.5.3c shows the percentage and number of surfaces with Schmorl's nodes, the average number of surfaces affected and the percentage and number of individuals affected in each of the artefact groups.

Artefact Group	% SN	Number SN	Average SN	Sk affected
Group A	26	155	9	76 (13)
Group B	19	49	8	83 (5)
Group C	21	45	8	83 (5)
Group D	42	41	14	100 (3)

Table 4.5.3c: Percentage and number of surfaces with Schmorl's nodes, average number of vertebral surfaces and percentage and number of individuals affected from each of the artefact groups. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

Across the whole vertebral column, Group D had the highest percentage of Schmorl's nodes, the highest average number of surfaces affected and the highest percentage of individuals affected. However this group was very small, with only three individuals present, so it is likely that these results are biased by the small sample size.

Table 4.5.3d shows the distribution of Schmorl's nodes in the thoracic and lumbar regions of the vertebral column in each of the artefact groups. As the number of cervical vertebrae affected in each group was small (an average of around 1 Schmorl's node in each artefact group) this region was not compared between the artefact groups.

Artefact Group	Thoracic % SN	Thoracic No SN	Thoracic Av SN	Lumbar % SN	Lumbar No SN	Lumbar Av SN
Group A	34	11	7	27	40	2
Group B	26	33	6	19	12	2
Group C	25	30	5	28	15	3
Group D	40	22	7	48	14	5

Table 4.5.3d: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in the thoracic and lumbar vertebrae from individuals from each of the artefact groups. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

Figure 4.5.3a shows the average number of surfaces affected in each artefact group in the whole vertebral column and the thoracic and lumbar vertebrae. The error bars show the standard error of the mean (SEM), which gives an indication of how representative the average is of the whole sample. The large error bars for Group D suggest that the mean for this sample is not very representative of the spread of the data.

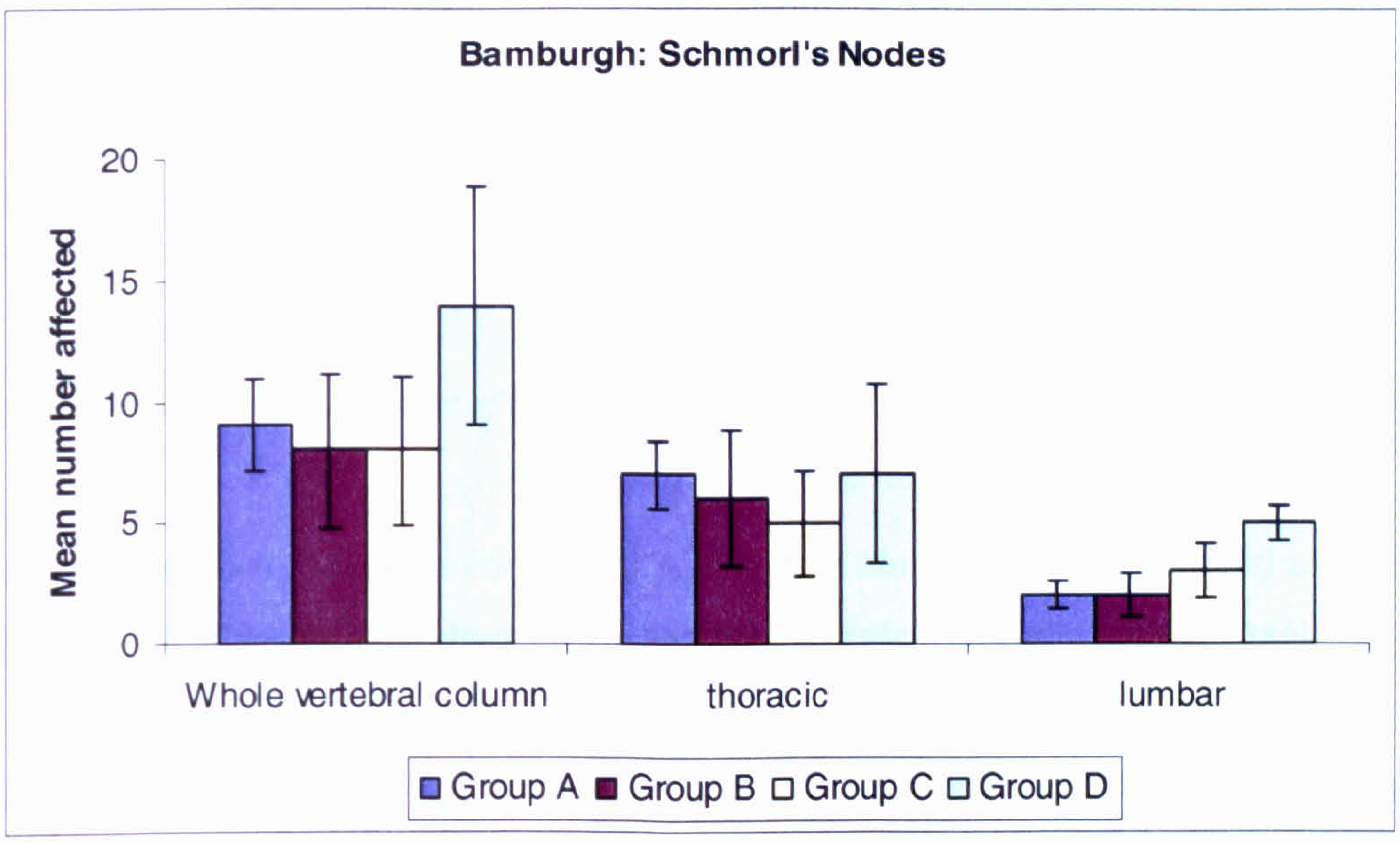


Figure 4.5.3a: The average number of Schmorl's nodes in each of the artefact groups at Bamburgh. Error bars - +/- SEM. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

As the results for Group D are probably artificially high, Group A should be considered to be the artefact group most frequently affected by Schmorl's nodes, although the average number of surfaces affected in the lumbar vertebrae was low in Group A. On the whole, the results were similar between Groups A, B and C, but as Group C had shown higher levels of changes to the joints and entheses when compared with the other groups, this group was compared with all other males (Figure 4.5.3b) to identify any variation between these individuals and the rest of the males from the skeletal sample from Bamburgh. This figure shows that the average number of Schmorl's nodes was lower in Group C than in all other males, except in the lumbar vertebrae, suggesting that the stress to the vertebral column may have been less in Group C than that experienced by all other males.

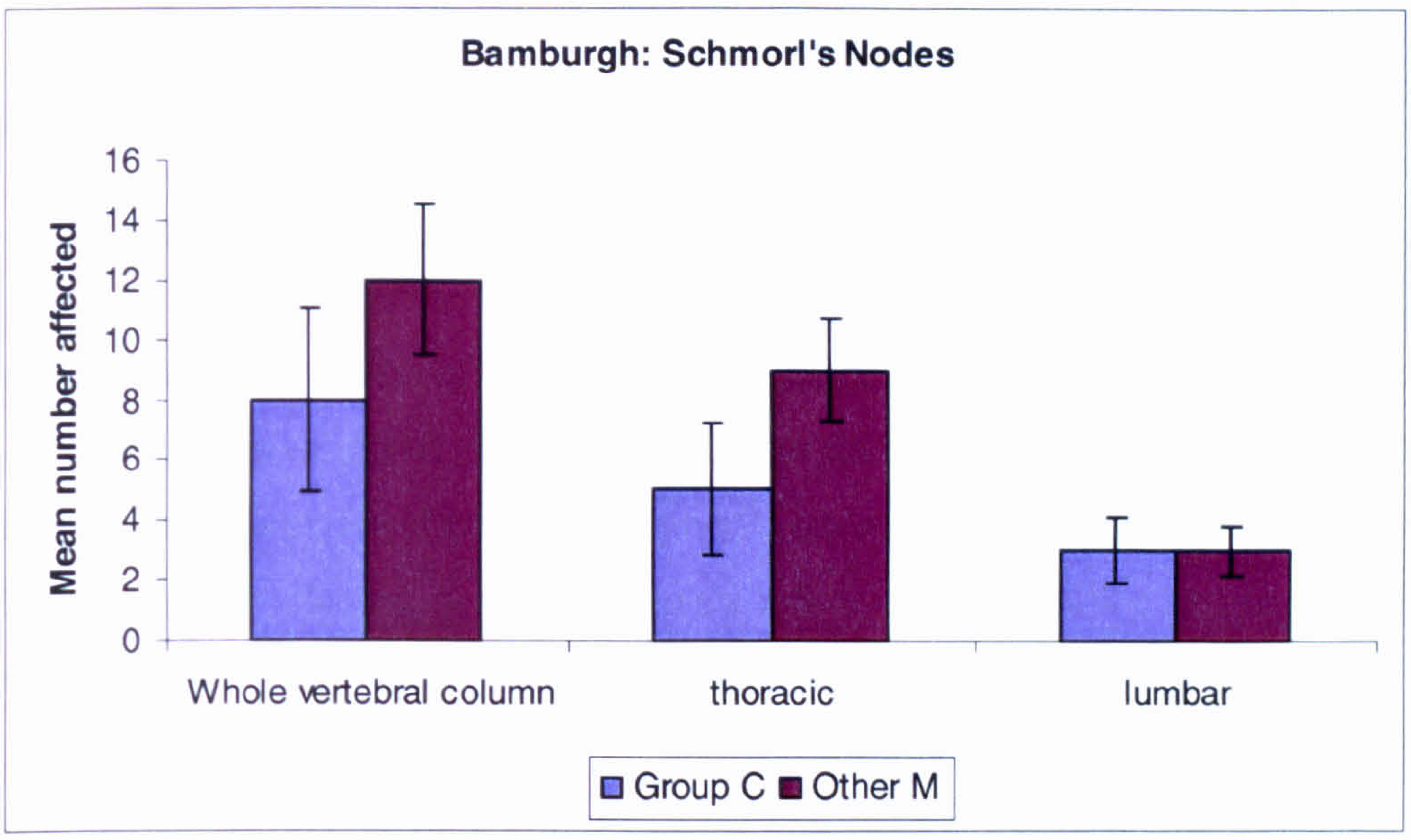


Figure 4.5.3b: The average number of Schmorl's nodes in Group C and all other males from Bamburgh. Error bars - +/- SEM.

Figure 4.5.3c shows the results for Group A, the individuals without any burial artefacts, compared with all other individuals from Bamburgh. This figure shows that, while the average number of surfaces affected in the whole vertebral column was the same, the thoracic vertebrae were more affected in Group A, but the lumbar vertebrae had fewer Schmorl's nodes on average than other individuals.

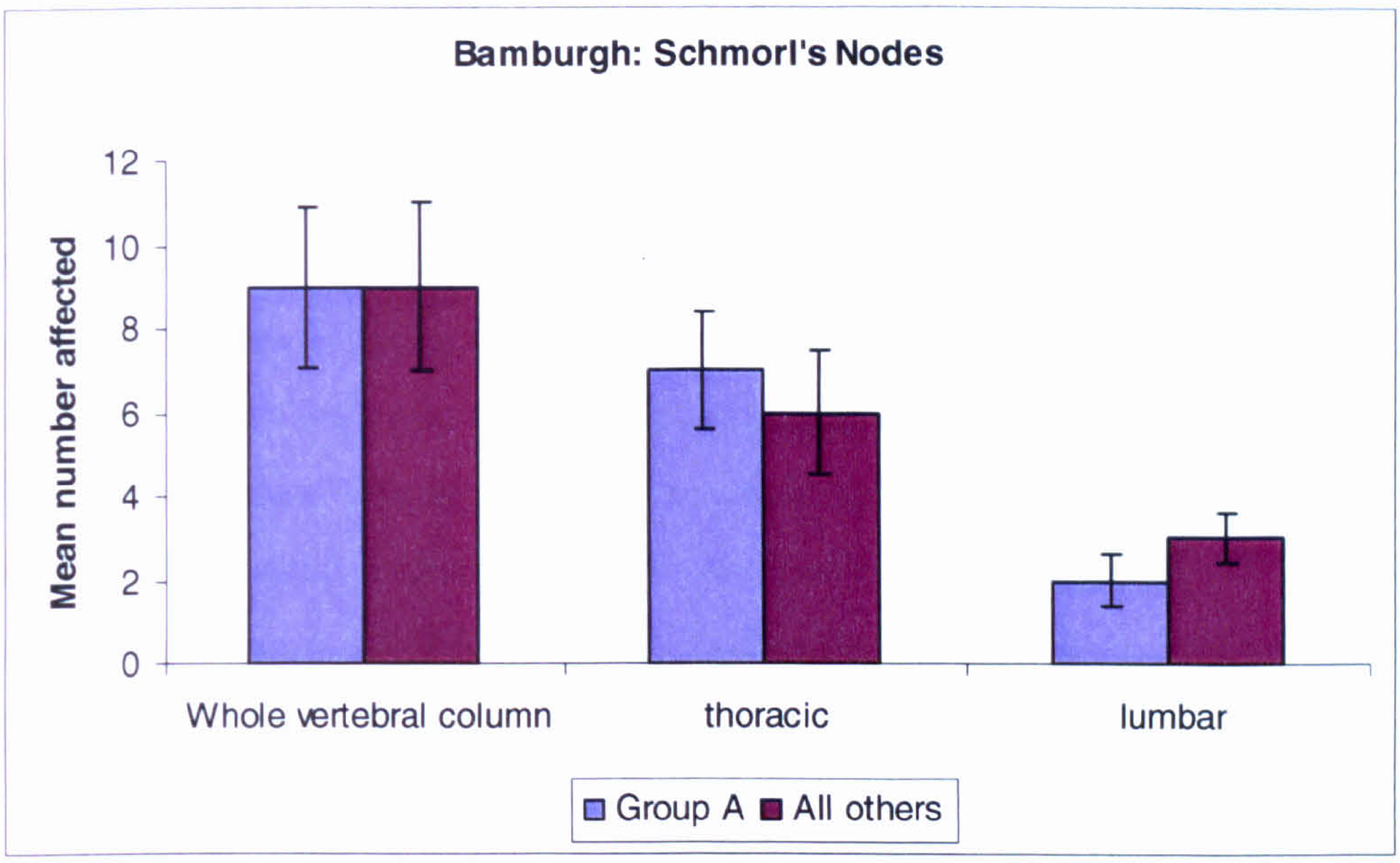


Figure 4.5.3c: The average number of Schmorl's nodes in each of the artefact groups at Castledyke South. Error bars - +/- SEM.

Figures showing the location of Schmorl's nodes in the vertebral column in each of the four artefact groups are given in Appendix 4.3. Variation was seen in the regions of the vertebral column that were affected by Schmorl's nodes; in Group A, the region from T6 to T9 was the most affected, particularly on the inferior surfaces of the vertebrae. There were also peaks in the percentage of surfaces affected in the regions of T11 and L2.

In Group B, the percentage of Schmorl's nodes was much the same across the mid-thoracic to lumbar region, with peaks at T9 and L2, but generally the percentage of surfaces affected was lower than that seen in Group A. In Group C the percentage of Schmorl's nodes was greatest in the region of L1, with none of the cervical or thoracic vertebrae above T4 being affected. Group D individuals had a wide range of surfaces affected and had the highest frequencies of cervical vertebrae affected, but the number of individuals in this group was small, as is shown by the low percentages of vertebral surfaces present in figure 4.5.3g.

4.5.4: Norton Bishopsmill

From the total skeletal sample of 40 individuals, 18 individuals had vertebral columns with vertebral surfaces that were well preserved enough to be examined for the presence or absence of Schmorl's nodes. One individual with vertebral surfaces present was of unknown sex, eight were male, with an average of nine Schmorl's nodes each, and nine individuals were female with an average of two Schmorl's nodes. The number of Schmorl's nodes in male vertebral columns was significantly higher than the number seen in females (single factor ANOVA p= 0.01). Norton Bishopsmill was the only site where the average number of Schmorl's nodes differed significantly between the sexes.

	Cervical		Thoracic		Lumbar		Sk
Sex	Superior	Inferior	Superior	Inferior	Superior	Inferior	affected
Female	0 (0)	1 (5)	2 (4)	10 (18)	5 (16)	1 (4)	4 (44)
Male	0 (0)	0 (0)	17 (29)	26 (44)	15 (35)	13 (35)	7 (88)

Table 4.5.4a: The number and percentage of Schmorl's nodes observed in the Norton Bishopsmill sample according to sex and location in the vertebral column. The percentage of surfaces affected in each region of the vertebral column is shown in brackets. The number and percentage of individuals affected is also given.

Table 4.5.4a shows the number of Schmorl's nodes observed in males and females from the Norton Bishopsmill sample, in the cervical, thoracic and lumbar regions of the vertebral column, and the percentage of the total number of surfaces observed in each region of the vertebral column that were affected by Schmorl's nodes. The number and percentage of individuals affected is also given. The percentage of males with Schmorl's nodes was double that seen amongst females. In both sexes the cervical vertebrae were the least affected by Schmorl's nodes, and the thoracic region of the vertebral column was the most affected. More Schmorl's nodes were seen in males than in females, in all regions of the vertebral column. The numbers of Schmorl's nodes on the inferior surfaces of the thoracic vertebrae were significantly higher than those seen on the superior surfaces (chi squared p= 0.01).

i) Schmorl's nodes and Age

Table 4.5.4b shows the percentage and number (in brackets) of vertebral surfaces with Schmorl's nodes, from males and females across the whole vertebral column, the average number of Schmorl's nodes in each of the age groups and the percentage and number of individuals affected. As the number of individuals with preserved vertebrae was very small in the Norton Bishopsmill sample, the results for the two sexes were combined. Additionally, as only one individual fell into the Young/Middle age group, the Young and Young/Middle age groups were combined.

Age Group	SN	Average SN	Sk affected
Younger	5 (5)	1	40 (2)
Middle	20 (47)	6	75 (6)
Older	34 (43)	9	80 (4)

Table 4.5.1b: Number and percent of vertebral surfaces observed with Schmorl's nodes, the average number of surfaces affected and the percentage and number of individuals affected in each of the age groups: Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

The younger individuals had the lowest percentage of surfaces with Schmorl's nodes, and the lowest percentage of individuals affected. The highest percentage was seen in the Middle age group, but on average the Older age group had the most vertebral surfaces affected per individual, although this difference was not significant (ANOVA p=0.1)

In the Young and Young/Middle age groups, no Schmorl's nodes were seen in the cervical vertebrae and, in the thoracic vertebrae, only the inferior surface of the ninth thoracic vertebra was affected. Of the lumbar vertebrae in these individuals, Schmorl's nodes affected L1, L2 and L3. The range of vertebrae affected by Schmorl's nodes was much greater in the Middle aged adults, with all of the vertebral surfaces between the inferior surface of T7 and the superior surface of L3 being affected by Schmorl's nodes. The vertebral surface most frequently affected by Schmorl's nodes in the Middle age group was the inferior surface of the tenth thoracic vertebra. The Older age group showed the widest range of vertebral surfaces, although none of the cervical vertebrae were affected. The Older age group overall had higher percentages of the vertebral surfaces with Schmorl's nodes than either of the other age groups, and was the only group where the inferior L4 and superior L5 surfaces were affected.

ii) Schmorl's Nodes and Status

Table 4.5.4c shows the percentage and number of surfaces with Schmorl's nodes, the average number of surfaces affected and the percentage and number of individuals affected in each of the artefact groups. As there were only two individuals in Group C and four individuals from Group D, the data from these groups were combined in order to increase sample size. There were no individuals from Group B with vertebral surfaces present for observation.

Artefact Group	% SN	Number SN	Average SN	Sk affected
Group A	23	81	7	75 (9)
Group C +D	11	14	2	50 (3)

Table 4.5.4c: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in individuals from each of the artefact groups. Group A – no artefacts, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Across the whole vertebral column, Group A had the highest percentage of Schmorl's nodes, and the highest average number of surfaces affected, but the difference between Group A and the other artefact groups was not significant (ANOVA p= 1.3).

Table 4.5.4d shows the distribution of Schmorl's nodes in the thoracic and lumbar regions of the vertebral column in each of the artefact groups. As only a single cervical vertebra was affected in the Norton Bishopsmill sample, this region was not compared between the artefact groups.

Artefact Group	Thoracic			Lumbar		
	% SN	No SN	Av SN	% SN	No SN	Av SN
Group A	29	54	5	27	26	2
Group C +D	10	6	1	20	8	1

Table 4.5.4d: Percentage and number of surfaces with Schmorl's nodes and average number of vertebral surfaces affected in the thoracic and lumbar vertebrae from individuals from each of the artefact groups. Group A – no artefacts, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

Again, Group A had a higher percentage and average number of Schmorl's nodes than all the other individuals, in both the thoracic and lumbar regions of the vertebral column.

Figure 4.5.4a shows the average number of surfaces affected in each artefact group in the whole vertebral column, and in the thoracic and lumbar vertebrae. The error bars show the standard error of the mean (SEM), which gives an indication of how representative the average is of the whole sample.

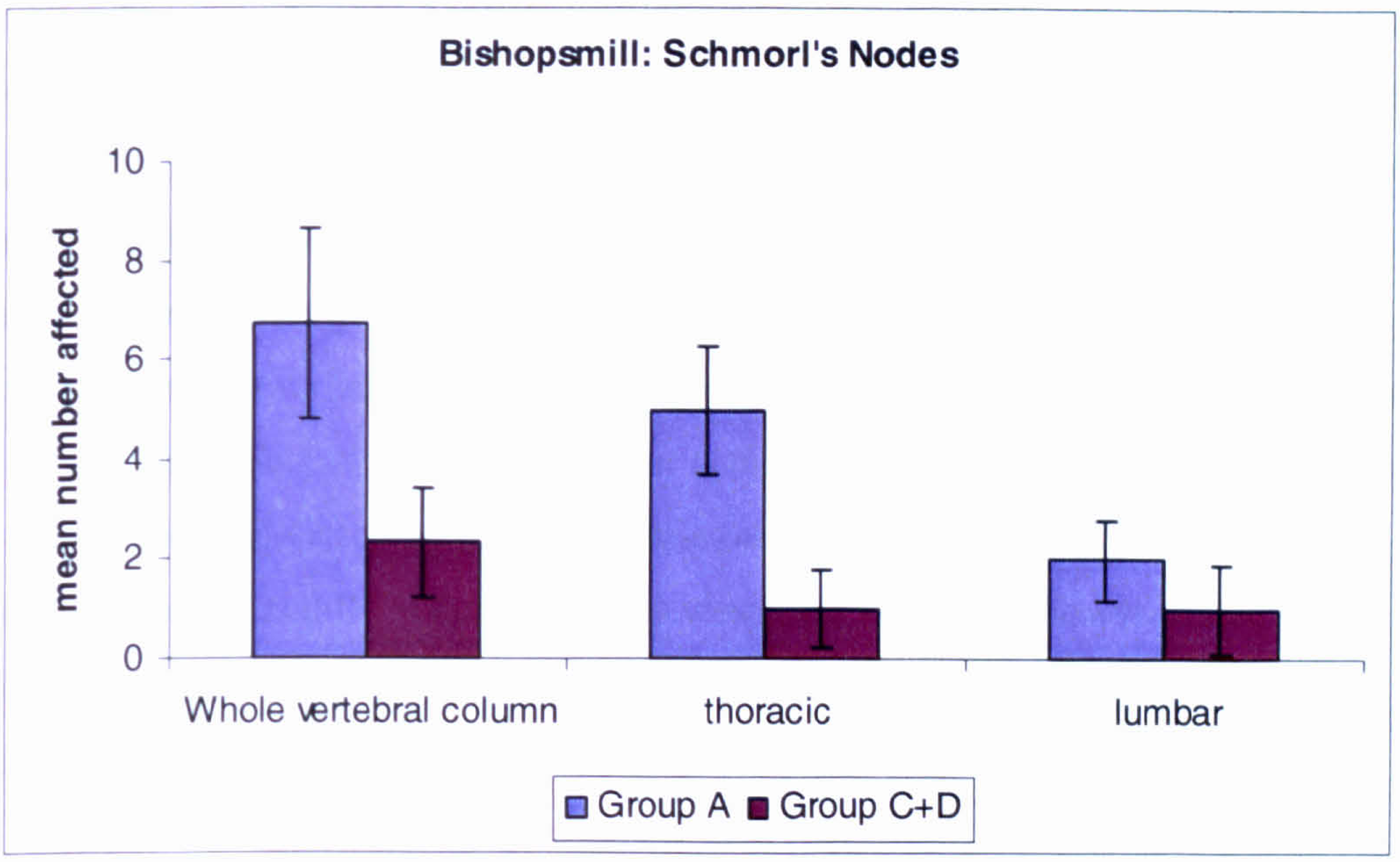


Figure 4.5.4a: The average number of Schmorl's nodes in each of the artefact groups at Norton Bishopsmill. Error bars - +/- SEM. Group A – no artefacts, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

This figure shows the difference between Group A, those with no burial artefacts, and the individuals from Groups C and D who were buried with some artefacts or coffin fittings. Although the differences in the numbers of Schmorl's nodes were not statistically significant at the 95% level of confidence, when tested with ANOVA tests (whole vertebral column $p = 0.1$, thoracic $p = 0.09$, lumbar $p=0.5$), the number of Schmorl's nodes in the thoracic vertebrae is significantly higher in Group A at the 90% level of confidence.

As individuals of both sexes were present in all groups from Norton Bishopsmill it is unlikely that these differences in the mean number of Schmorl's nodes are due to biological sex. These results suggest that another factor such as differences in levels of physical stress to the vertebral column may be a cause of this variation. These results are similar to those seen at Bamburgh, where Group A also had a higher average number of Schmorl's nodes in the thoracic vertebrae when compared with the rest of the sample, and at Castledyke and Norton Mill Lane where Group 1 individuals had relatively high mean numbers of Schmorl's nodes.

Figures showing the location of Schmorl's nodes in the vertebral column in Group A and Groups C and D. There is no Figure showing results for Group B as no individuals from this group had surviving vertebral surfaces. Group A was the only group with Schmorl's nodes in the cervical vertebrae and also had the widest range of vertebral surfaces affected of the artefact groups. However, the number of individuals in Group A with preserved vertebral surfaces (12 individuals) was much larger than the other Groups, so this may be an artefact of poor preservation in the other groups. In Group A the eleventh and twelfth thoracic vertebrae had the highest percentage of surfaces with Schmorl's nodes. In Group C and D, Schmorl's nodes were only seen in the lower thoracic and lumbar vertebrae, but the percentage of vertebral surfaces present in Groups C and D was small in most regions of the vertebral column.

Summary: Schmorl's Nodes

- The prevalence of Schmorl's nodes was significantly higher on the inferior surfaces of the vertebrae than on the superior surfaces in all four samples

- Castledyke South and Bamburgh had the highest average numbers of Schmorl's nodes, and Norton Bishopsmill had the lowest.

- At all four sites there was a slight but not significant increase in the prevalence of Schmorl's nodes with age, although there was more of an association between Schmorl's nodes and age at Bamburgh and Norton Bishopsmill.

- Males generally had more Schmorl's nodes than females, but this difference was only significant at Norton Bishopsmill.

- At Castledyke South, and Norton Mill Lane males buried with weapons (Group 3) had the highest average number of Schmorl's nodes, even when compared with other males from these sites.

- At Castledyke and Mill Lane Group 4 individuals, those with the most complex grave goods, had on average the fewest surfaces with Schmorl's nodes.

- At Bamburgh and Norton Bishopsmill, the average numbers of Schmorl's nodes were highest in Group A, the individuals with no artefacts

- At Bamburgh, Group C had a low average number of Schmorl's nodes, even when compared with all other males from the sample. At Norton Bishopsmill, Groups C and D had the lowest average number of Schmorl's nodes.

4.6: Asymmetry

The following section examines the patterns of asymmetry in the paired humeri and femora from each of the skeletal samples.

4.6:1: Castledyke South

From the 86 individuals examined from the sample of skeletons from Castledyke South, 23 pairs of humeri and 26 pairs of femurs from females were measured to examine bilateral asymmetry, while 25 pairs of male humeri and 25 pairs of femurs were measured. Table 4.6.1a shows the average difference, in millimetres, between the measurements of the right and left humeri (right minus left) in males and females, while Table 4.6.1b shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side). The larger the figure, the greater the degree of asymmetry in the measurements of the paired elements; where the figure was zero, there was no difference in the measurements of the two sides.

	M/L	A/P	Circ
Female	0.3	-0.1	0.4
Male	2.2	0.9	3.6

Table 4.6.1a: Average difference in millimetres between the right and left sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

	M/L	A/P	Circ
Female	1	0.8	1.7
Male	2.2	0.9	3.6

Table 4.6.2b: Average difference in millimetres between the larger and smaller sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

These tables show that at Castledyke the average difference between the right and left sides, and the difference between the larger and smaller sides, was greater in males than in females. The greatest degree of asymmetry was seen in the measurement of the circumference of the humerus in both sexes. The absolute difference in the degree of asymmetry was significantly greater in males than in females for the medio-lateral diameter and the circumference, but not for the antero-posterior diameter (ANOVA: M/L p = 0.0001, A/P p = 0.8, circumference p= 0.0001). In males, all the figures in Table 4.6.1a were positive, indicating that the right humerus was larger on average than the left side. However, in females the average difference between the right and left sides was positive in the medio-lateral diameter and circumference but negative in the antero-posterior diameter. This indicates that the antero-posterior diameter of the humerus was larger on average on the left side than the right.

Table 4.6.1c shows the average difference, in millimetres, between the measurements of the right and left paired femora (right minus left) in males and females, while Table 4.6.1d shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side).

	M/L	A/P	Circ
Female	-0.9	-0.3	-0.9
Male	-0.5	-0.4	-0.7

Table 4.6.1c: Average difference in millimetres between the right and left sides of the femur in the medio-lateral diameter, antero-posterior diameter and circumference in males and females.

	M/L	A/P	Circ
Female	1.1	0.8	1.6
Male	1.1	1	1.9

Table 4.6.1d: Average difference in millimetres between the larger and smaller sides of the femur in the medio-lateral diameter, antero-posterior diameter and circumference in males and females.

In Table 4.6.1c, the negative values indicate that the left element was larger on average than the right in all three measurements, showing that the direction of asymmetry in the pairs of femurs tended to be towards the left, in both males and females. Table 4.2.6d shows that the difference in the medio-lateral and antero-posterior diameter was similar in both sexes, while the difference in circumference was marginally greater in males, but this difference was not significant (ANOVA p= 0.5)

i) Asymmetry and Age

When the sample was subdivided into age groups, the number of individuals with paired humeri and femora in each group was reduced, so a weighted mean was calculated for each group, to reduce the impact of any outlying measurements. As it has been established that the right humerus was generally larger than the left side, and that the left femur was generally larger than the right in both sexes, the following sections will only examine the absolute difference between the sides (larger side minus smaller side). Table 4.6.1e shows the average absolute asymmetry, in millimetres, in the paired humeri in each of the age groups, and the number of paired humeri measured in each group.

Age Group	number	M/L	AP	Circ
Young	11	1.7	0.2	3.5
Young/Middle	9	1.2	0.6	1.1
Middle	12	1.1	0.6	2.3
Older	17	1.9	0.5	2.8

Table 4.6.1e:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the age groups. Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

While the mean differences in the antero-posterior and medio-lateral diameters were similar between the age groups, the mean asymmetry in the circumference from the Young/Middle age group was significantly smaller than the other age groups (ANOVA $p= 0.01$). Table 4.6.1f shows the average absolute asymmetry, in millimetres, in the paired femora in each of the age groups, and the number of paired femora measured in each group. The average asymmetry of all three measurements from the femur was similar between the age groups.

Age Group	number	M/L	AP	Circ
Young	7	0.6	0.4	1.1
Young/Middle	9	1	1.1	1.8
Middle	12	1.3	0.6	2
Older	21	0.8	0.6	1.1

Table 4.6.1f:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the age groups. Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

These results suggest that the degree of asymmetry between the larger and smaller sides of the paired humeri and femora was not strongly associated with increasing age at Castledyke.

ii) Asymmetry and Status

Table 4.6.1g shows the average absolute asymmetry in millimetres for the three measurements of the paired humeri from each of the artefact groups, and the number of paired humeri measured in each group

Artefact Group	number	M/L	AP	Circ
Group 1	14	1.3	0.6	2.9
Group 2	20	1.7	0.5	2.9
Group 3	6	2.3	0	3
Group 4	9	0.6	0.8	1.2

Table 4.6.1g:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

The weighted mean asymmetry was highest in the medio-lateral diameter and the circumference in Group 3, the males with weapons, while Group 4 had the lowest mean asymmetry in the medio-lateral diameter and circumference. Figure 4.6.1a shows the weighted mean asymmetry of the humeri in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements. From this figure the small average degree of asymmetry in Group 4 is apparent. Groups 1 and 2 had similar levels of mean asymmetry, particularly in the asymmetry of the humeral circumference.

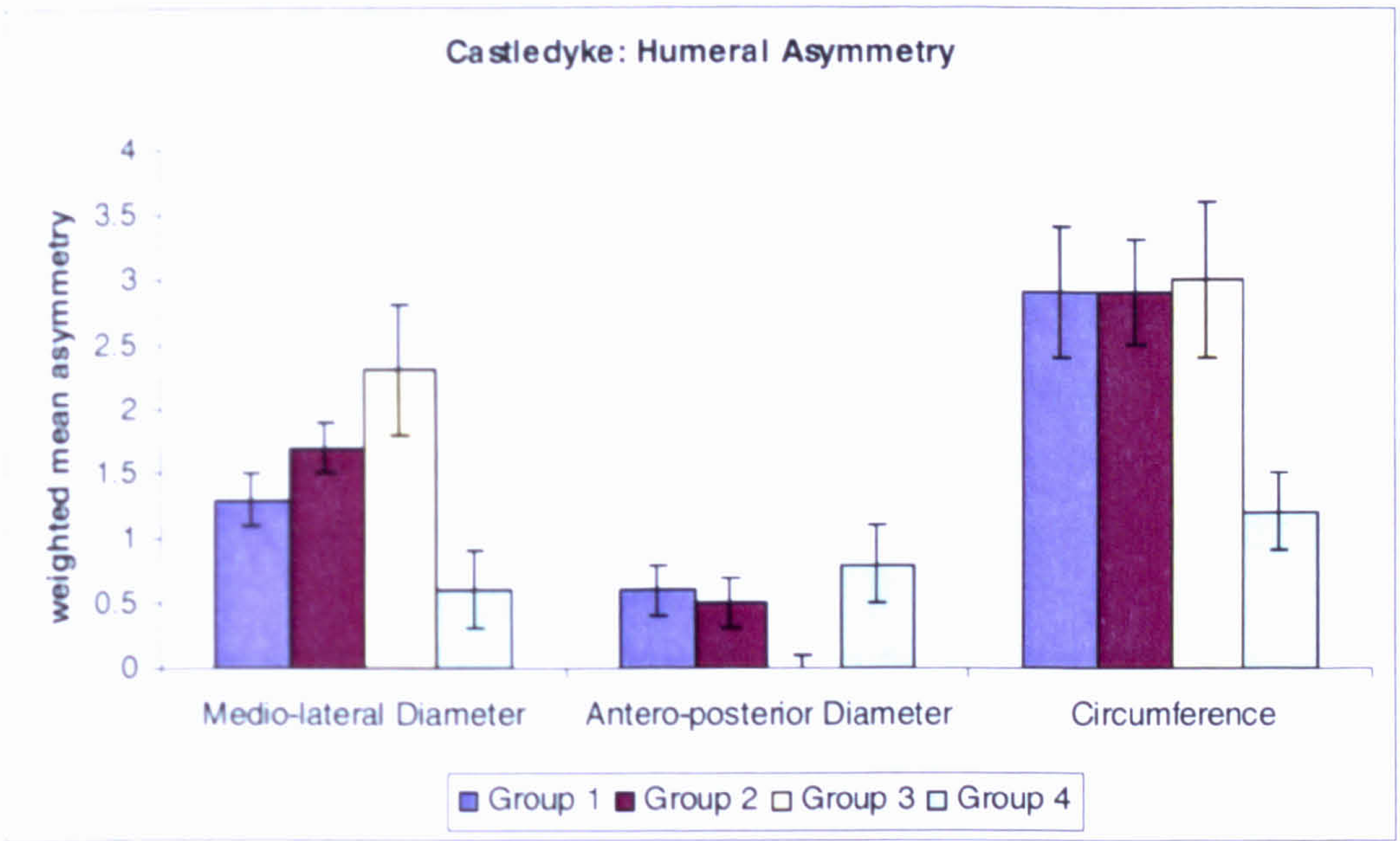


Figure 4.6.1a: The weighted mean absolute asymmetry of the humeri in each of the artefact groups from Castledyke South. Error bars - +/- SEM. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

As Group 3 individuals were all male and Group 4 was entirely female, these groups were compared with all other males and all other females, to establish whether the differences seen in these two groups were an artefact of differences in sex. Figure 4.6.1b shows the weighted mean asymmetry of the humerus in Group 3 and all other males.

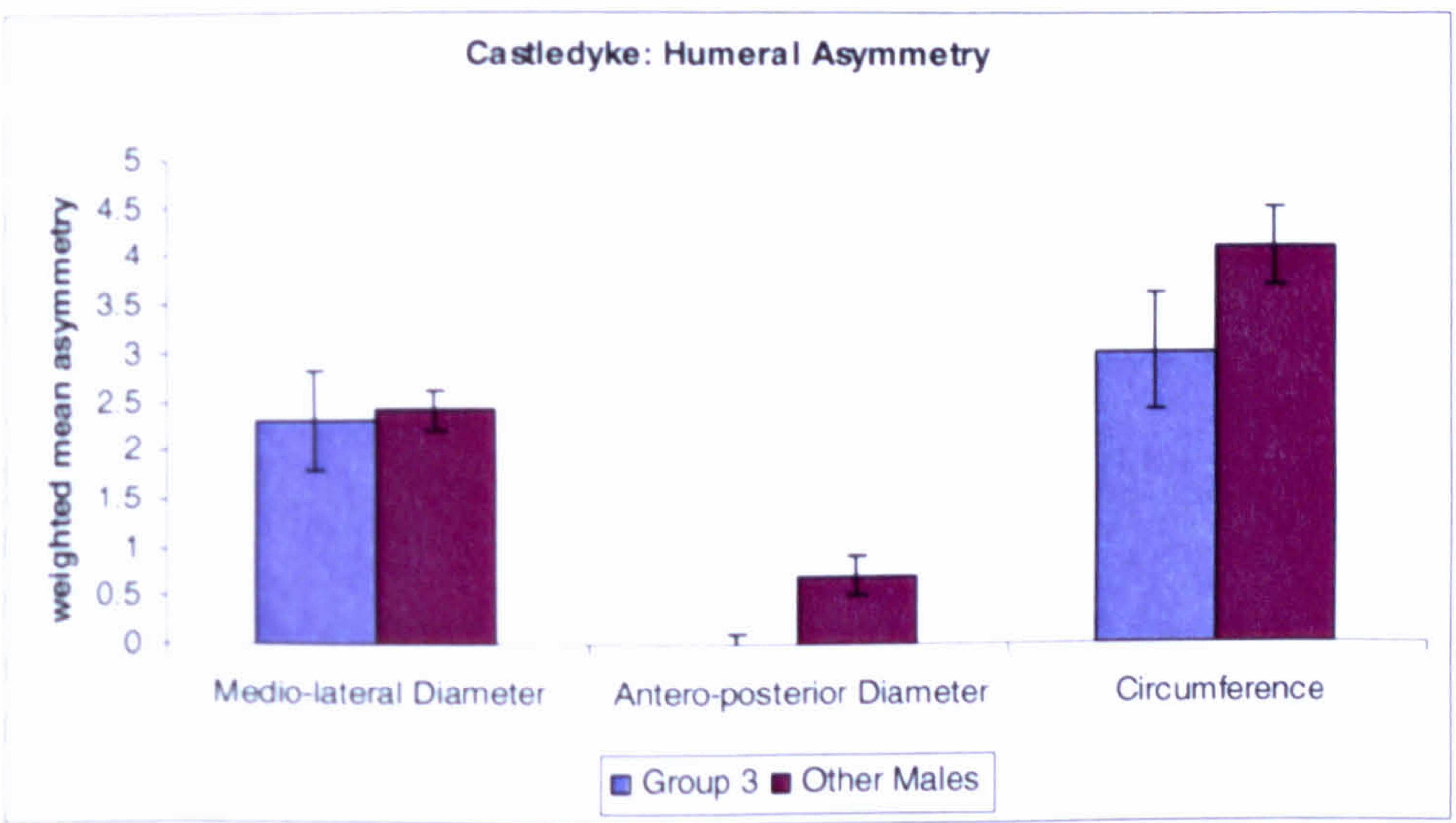


Figure 4.6.1b: The weighted mean absolute asymmetry of the humeri in Group 3 and all other males from Castledyke South. Error bars - +/- SEM

This figure shows that, when compared with other males, the degree of asymmetry of all of the measurements from Group 3 was less than that seen in all other males. Group 3 males were, on average, more symmetrical than all other males from Castledyke. Figure 4.6.1c shows the results for Group 4, compared with all other females from Castledyke South. While Group 4 had smaller mean asymmetries of the medio-lateral diameter and circumference when compared with other females, the degree of asymmetry in the antero-posterior diameter was greater in Group 4 females. None of these differences were statistically significant (ANOVA; M/L p= 0.6, A/P p=0.6, circumference p=0.6).

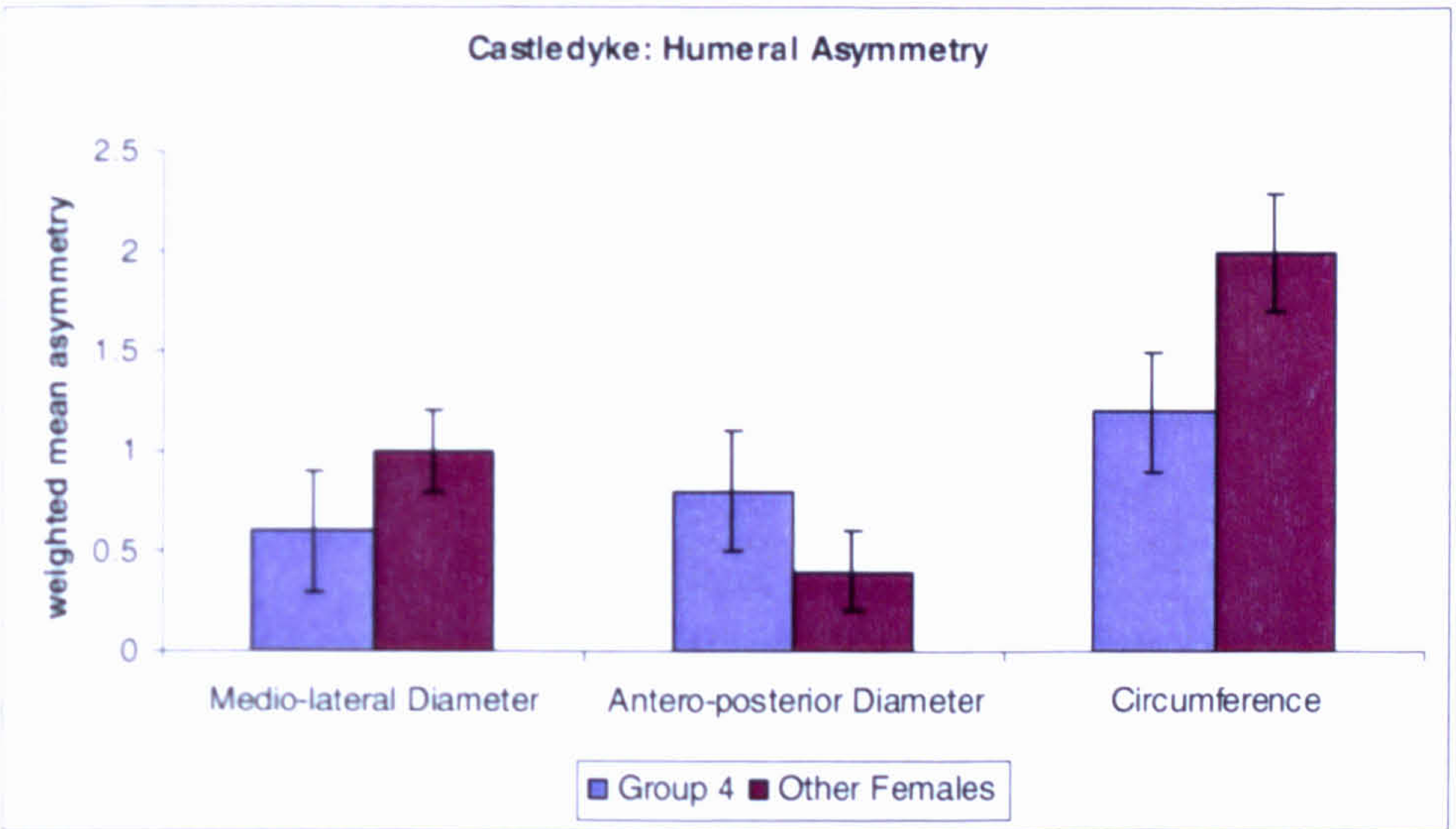


Figure 4.6.1c: The weighted mean absolute asymmetry of the humeri in Group 4 and all other females from Castledyke South. Error bars - +/- SEM

Table 4.6.1h shows the average absolute asymmetry in millimetres for the three measurements of the paired femora from each of the artefact groups, and the number of paired femora measured in each group

Artefact Group	number	M/L	AP	Circ
Group 1	17	1.4	0.8	1.9
Group 2	19	0.7	0.7	0.8
Group 3	6	1	1.2	1.3
Group 4	10	0.7	0.2	1.5

Table 4.6.1h: Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. . Group 1 – No items or a single bead, potsherd or animal bone. Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Figure 4.6.1d shows the weighted mean asymmetry of the femora in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements.

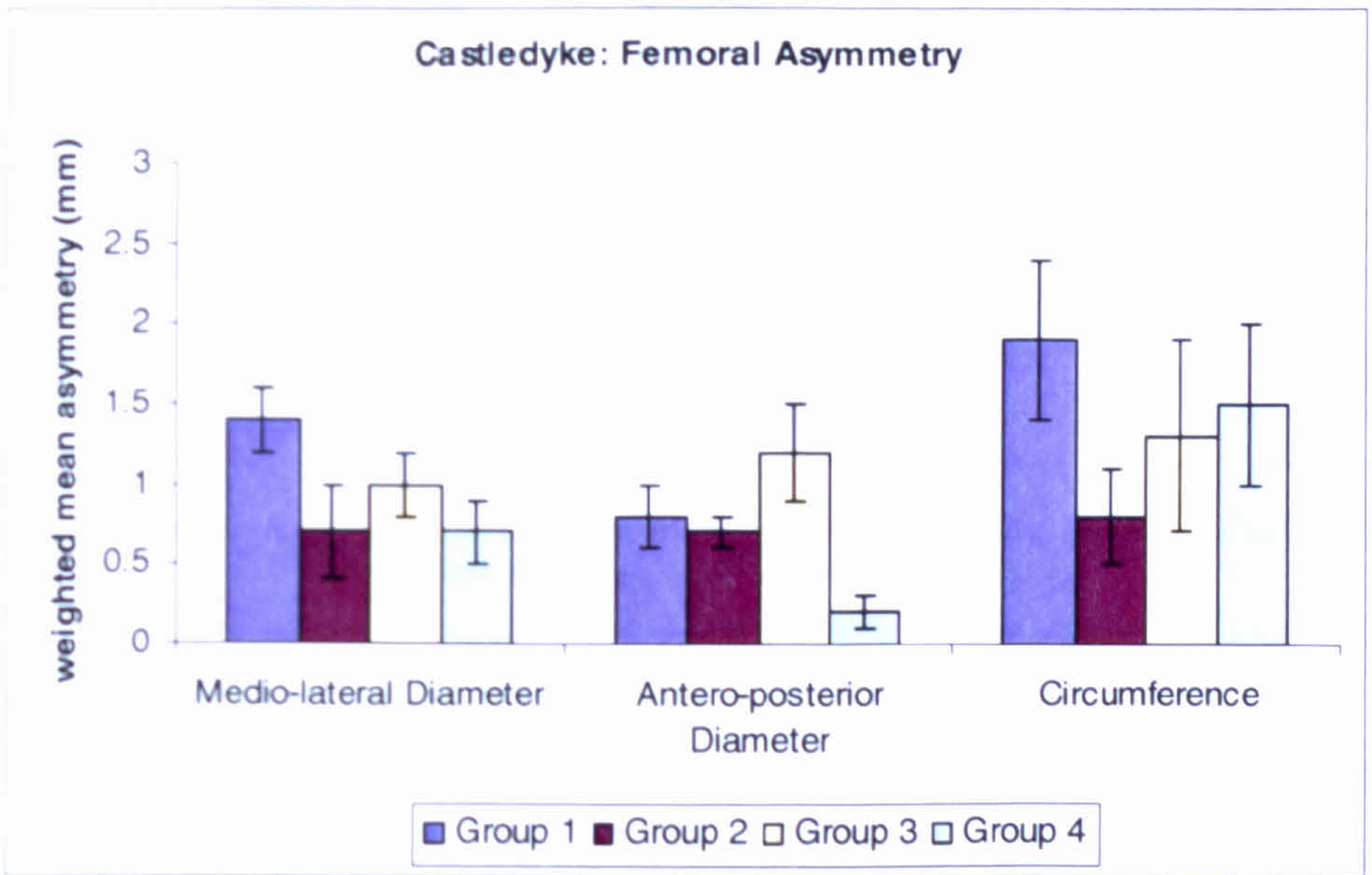


Figure 4.6.1d: The weighted mean absolute asymmetry of the femora in each of the artefact groups from Castledyke South. Error bars - +/- SEM. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

The patterns of asymmetry in the femur were rather different to those seen in the paired humeri. Group 1 had the greatest degree of asymmetry in the medio-lateral diameter and circumference, and Group 3 had the greatest degree of asymmetry in the antero-posterior diameter, and relatively high degrees of asymmetry in both of the other measurements. As with the upper limb, the results from Group 3 were compared with all other males and the results from Group 4 were compared with all other females. Figure 4.6.1e shows that when compared with all other males, Group 3 femora were more asymmetrical than all other males in the antero-posterior diameter and circumference, but the degree of medio-lateral asymmetry was the same in both groups.

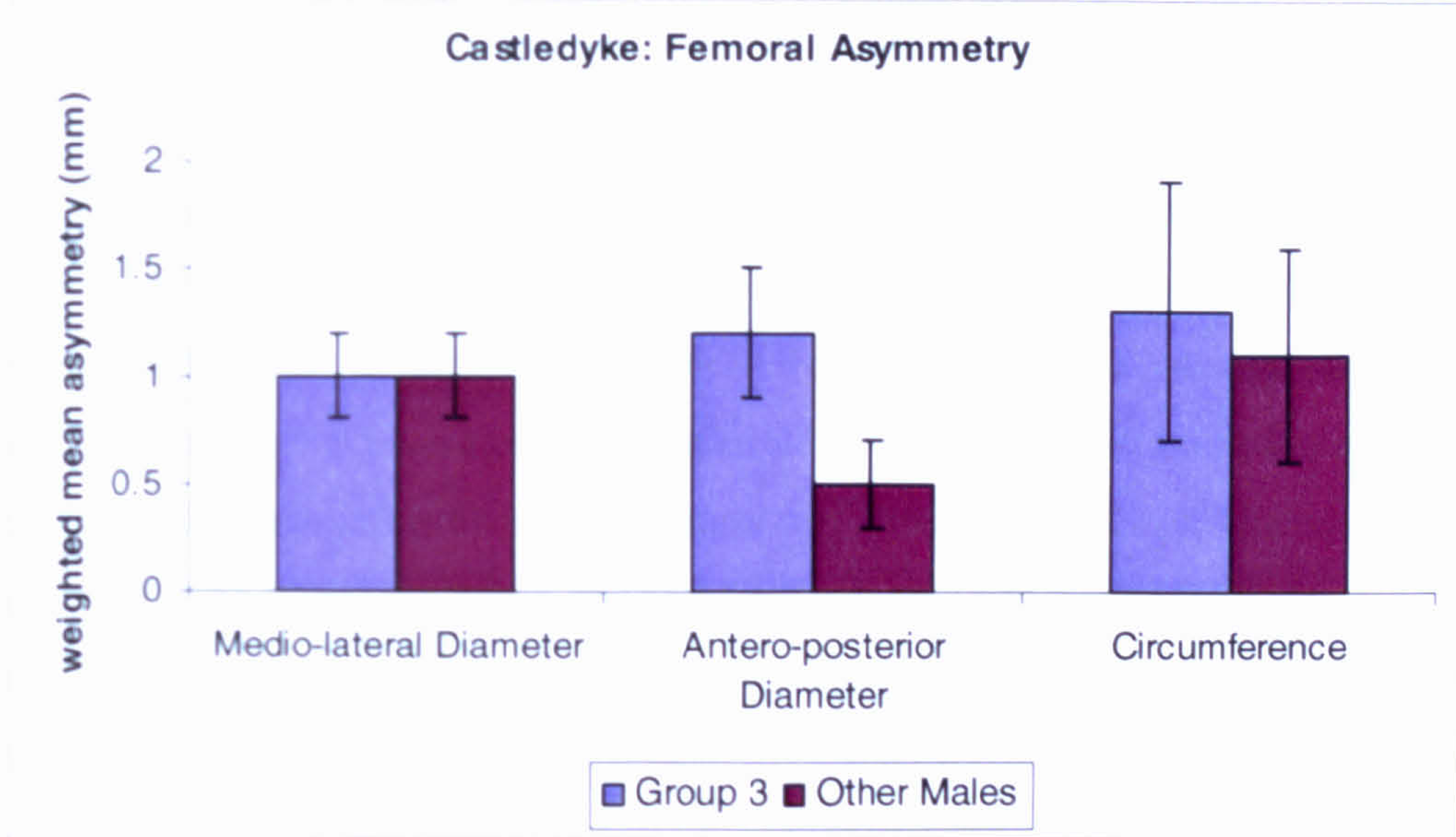


Figure 4.6.1e: The weighted mean absolute asymmetry of the femora from Group 3 and all other males from Castledyke South. Error bars - +/- SEM

Figure 4.6.1f shows the mean asymmetry of the femora from Group 4 and all other females at Castledyke. While the weighted mean asymmetry in the circumference was the same, the degree of asymmetry in the medio-lateral and antero-posterior diameter was smaller in Group 3 than in all other females, and for the antero-posterior diameter this difference was statistically significant (ANOVA p=0.02).

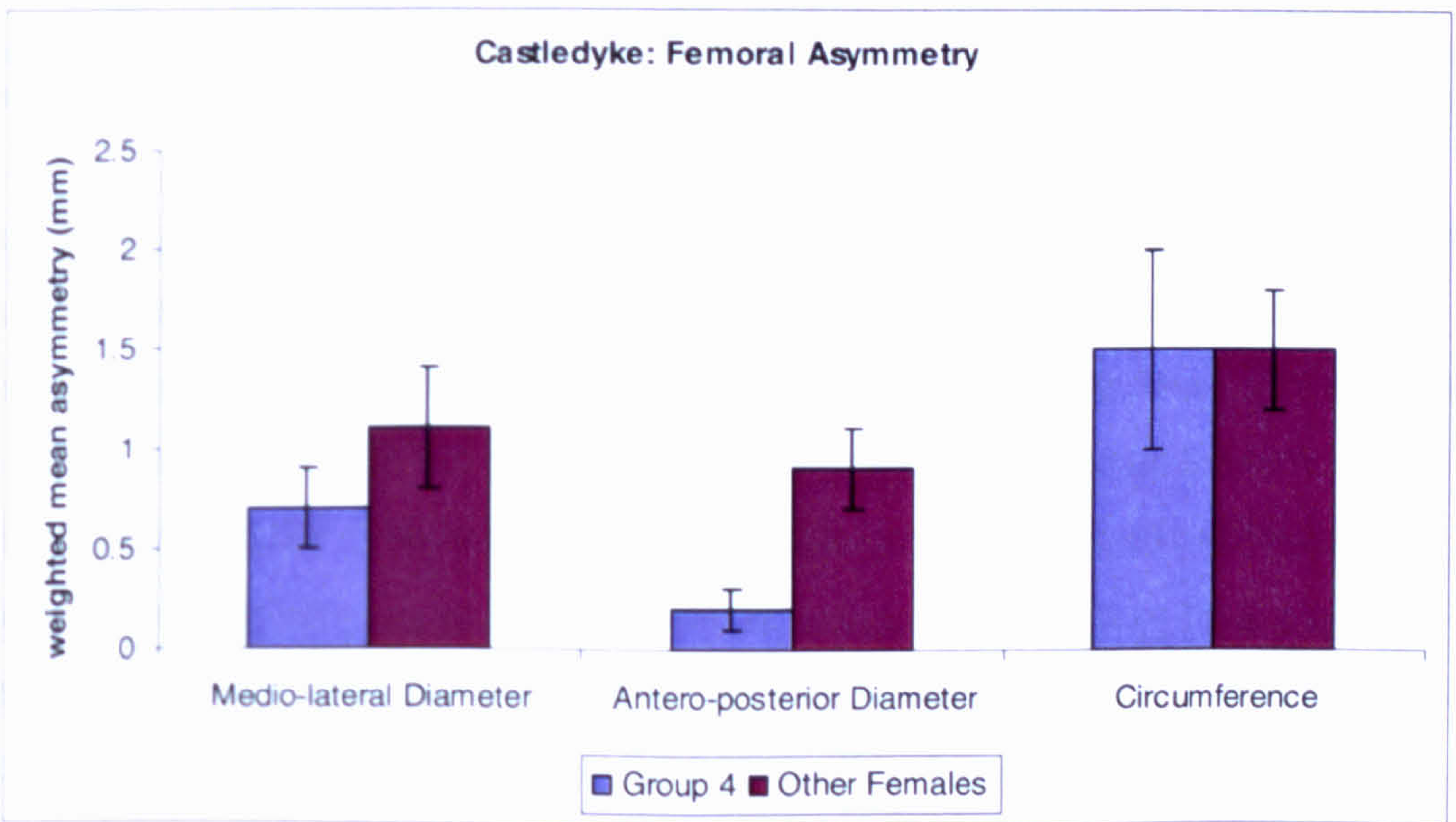


Figure 4.6.1f: The weighted mean absolute asymmetry of the femora from Group 4 and all other females from Castledyke South. Error bars - +/- SEM

4.6:2: Norton Mill Lane

From the 51 individuals from the Norton Mill Lane skeletal sample, 11 pairs of humeri and 17 pairs of femurs from females were measured to examine bilateral asymmetry, while 20 pairs of male humeri and 25 pairs of femurs were measured. Table 4.6.2a shows the average difference, in millimetres, between the measurements of the right and left humeri (right minus left) in males and females, while Table 4.6.2b shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side). The larger the figure, the greater the degree of asymmetry in the measurements of the paired elements; where the figure was zero, there was no difference in the measurements of the two sides.

	M/L	A/P	Circ
Female	0.9	-0.1	0.4
Male	1.7	0.5	3.3

Table 4.6.2a: Average difference in millimetres between the right and left sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

	M/L	A/P	Circ
Female	1.2	0.9	2.2
Male	1.8	1.5	3.2

Table 4.6.2b: Average difference in millimetres between the larger and smaller sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

These tables show that, for the humeri, the average difference between the right and left sides and the larger and smaller sides was greater in males than in females, and the greatest degree of asymmetry was seen in the circumference in both sexes. For the males, the figures in Table 4.6.2a were all positive, indicating that on average the direction of asymmetry was to the right, but in the females the average difference in the antero-posterior diameter between left and right was negative, indicating than on average the left side was larger for this measurement. The antero-posterior diameter also had the smallest average difference between the larger and smaller sides, for all the measurements. The degree of absolute asymmetry (larger side minus smaller) in the circumference in males was significantly larger than that seen in females (ANOVA p=0.01).

	M/L	A/P	Circ
Female	-0.5	-0.1	-0.9
Male	-0.3	0.4	0.4

Table 4.6.2c: Average difference in millimetres between the right and left sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

Table 4.6.2c shows the average difference, in millimetres, between the measurements of the right and left femurs (right minus left) in males and females, while Table 4.6.2d shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side).

	M/L	A/P	Circ
Female	1	1	2.3
Male	0.8	1.1	2.3

Table 4.6.2d: Average difference in millimetres between the larger and smaller sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference (Circ) in males and females.

The negative values in Table 4.6.2c indicate that in females, the left element was on average larger than the right in all three measurements, while in the males on average only the left medio-lateral diameter was larger than the right. As with the humerus, the greatest degree of asymmetry was seen in the measurement of the circumference in both sexes. However, unlike in the humerus, the average degree of asymmetry in the femur was very similar between the sexes. When these data were examined using single factor ANOVA tests, the variation seen in the average differences between the right and left sides, and the larger and smaller sides of the femurs were not statistically significant, for any of the three measurements.

i) Asymmetry and Age

As with Castledyke South, a weighted mean was calculated for each age group, to reduce the impact of any outlying measurements. Again, as it has been established that the right humerus was generally larger than the left side, and that the left femur was generally larger than the right in both sexes, the following sections will only examine the absolute difference between the sides (larger side minus smaller side).

Table 4.6.2e shows the average absolute asymmetry, in millimetres, in the paired humeri in each of the age groups, and the number of paired humeri measured in each group.

Age Group	number	M/L	AP	Circ
Young	8	1.1	1.1	1.7
Young/Middle	9	1.7	1.2	3.2
Middle	10	1.2	0.9	2.9
Older	4	1.9	0.5	0.8

Table 4.6.2e:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the age groups. Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

While there were some differences in the mean weighted absolute asymmetry between the artefact groups, these differences were not significant (ANOVA: M/L p= 0.6, A/P p= 0.6, circumference p= 0.2). These results show that age was not a factor in the degree of asymmetry seen in the paired humeri. Table 4.6.2f shows the average absolute asymmetry, in millimetres, in the paired femora in each of the age groups, and the number of paired femora measured in each group.

Age Group	number	M/L	AP	Circ
Young	11	0.3	0.9	0.7
Young/Middle	12	1	1	2.9
Middle	12	0.7	0.6	0.8
Older	6	1.3	1.1	2.5

Table 4.6.2f:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the age groups. Young = 17 to 25 years, Young/Middle = 26-30 years, Middle = 31- 40, Older = 41 + years.

As with the humeri, there was relatively little variation in the degree of asymmetry between the age groups; although there were differences in the average asymmetry of the circumference, these were not significant (ANOVA p = 0.3).

ii) Asymmetry and Status

Table 4.6.2g shows the average absolute asymmetry in millimetres for the three measurements of the paired humeri from each of the artefact groups, and the number of paired humeri measured in each group.

Artefact Group	number	M/L	AP	Circ
Group 1	5	1.1	1.9	1.2
Group 2	9	1.4	0.5	2.2
Group 3	8	1.9	1	4.2
Group 4	10	1.2	0.9	2.1

Table 4.6.2g: Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups.

Figure 4.6.2a shows the weighted mean asymmetry of the humeri in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements.

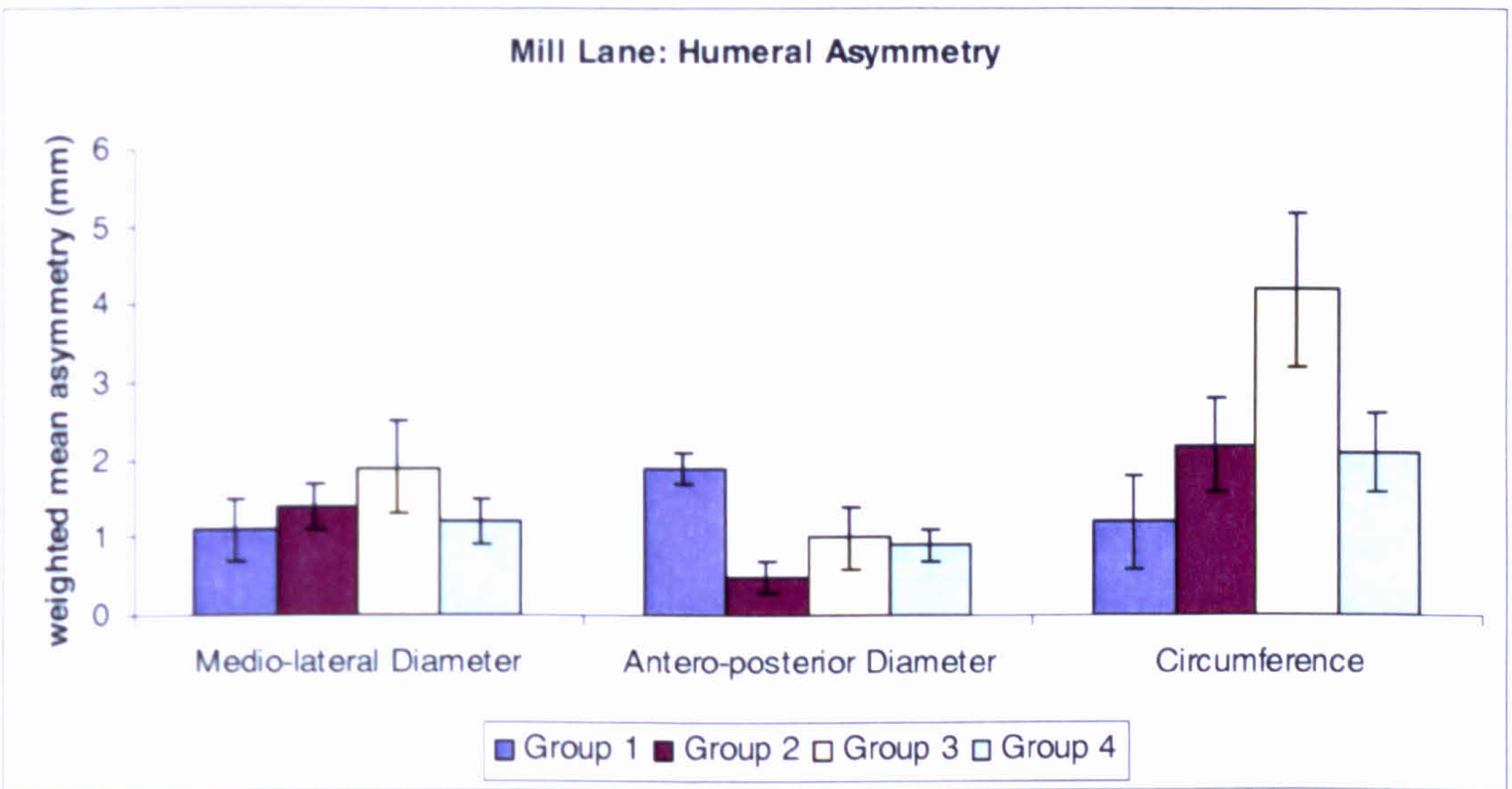


Figure 4.6.2a: The weighted mean absolute asymmetry of the humeri in each of the artefact groups from Mill Lane. Error bars - +/- SEM Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

Group 3 had the greatest degree of asymmetry in the medio-lateral diameter and circumference, while Group 1 had the smallest degree of asymmetry in these measurements, but the greatest degree of asymmetry in the antero-posterior diameter.

Although striking, the degree of asymmetry seen in the circumference of Group 1was not significantly smaller than that seen in all other individuals (ANOVA p=0.3). The degree of asymmetry seen in Group 2 was also small in the antero-posterior diameter, and generally this group appeared to be very similar to Group 4 in the pattern of humeral asymmetry.

As Group 3 individuals were all males this group was compared with all other males to establish whether the differences seen were an artefact of differences in sex. Figure 4.6.1b shows the weighted mean asymmetry of the humerus in Group 3 and all other males.

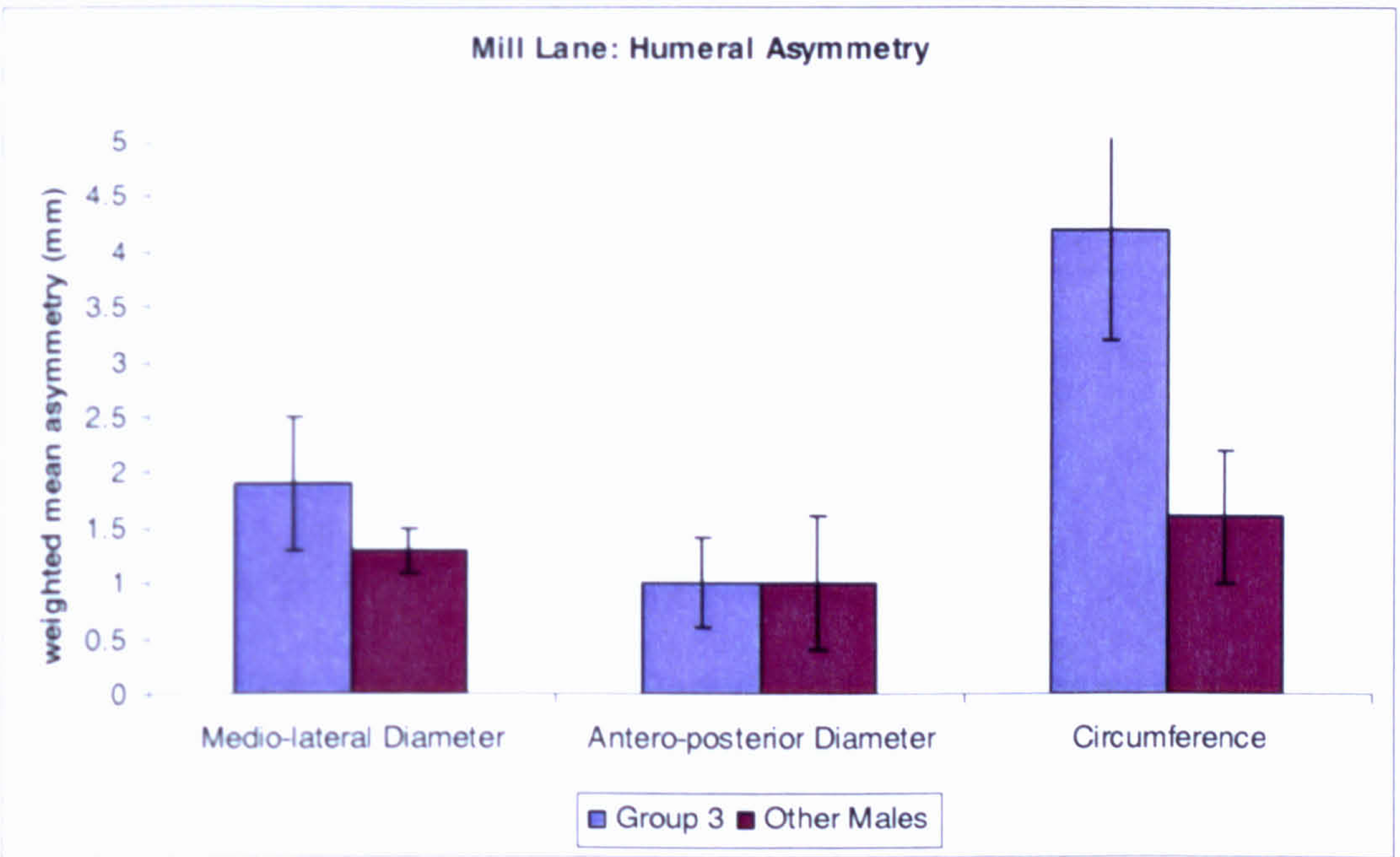


Figure 4.6.2b: The weighted mean absolute asymmetry of the humeri in Group 3 and all other males from Norton Mill Lane. Error bars - +/- SEM

The degree of asymmetry in the measurement of the circumference was significantly larger in Group 3 males than that seen in all other males from Norton Mill Lane (ANOVA p=0.02). This suggests that there may have been a difference in the patterns of physical stress between Group 3 males, those buried with weapons, and males that were not buried with weapons.

Table 4.6.2h shows the average absolute asymmetry in millimetres for the three measurements of the paired femora from each of the artefact groups, and the number of paired femora measured in each group

Artefact Group	number	M/L	AP	Circ
Group 1	5	0.4	1	2.7
Group 2	13	0.7	0.9	1.8
Group 3	7	0.7	1.2	3.7
Group 4	18	0.7	0.9	0.7

Table 4.6.2h: Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups.

Figure 4.6.2c shows the weighted mean asymmetry of the femora in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements.

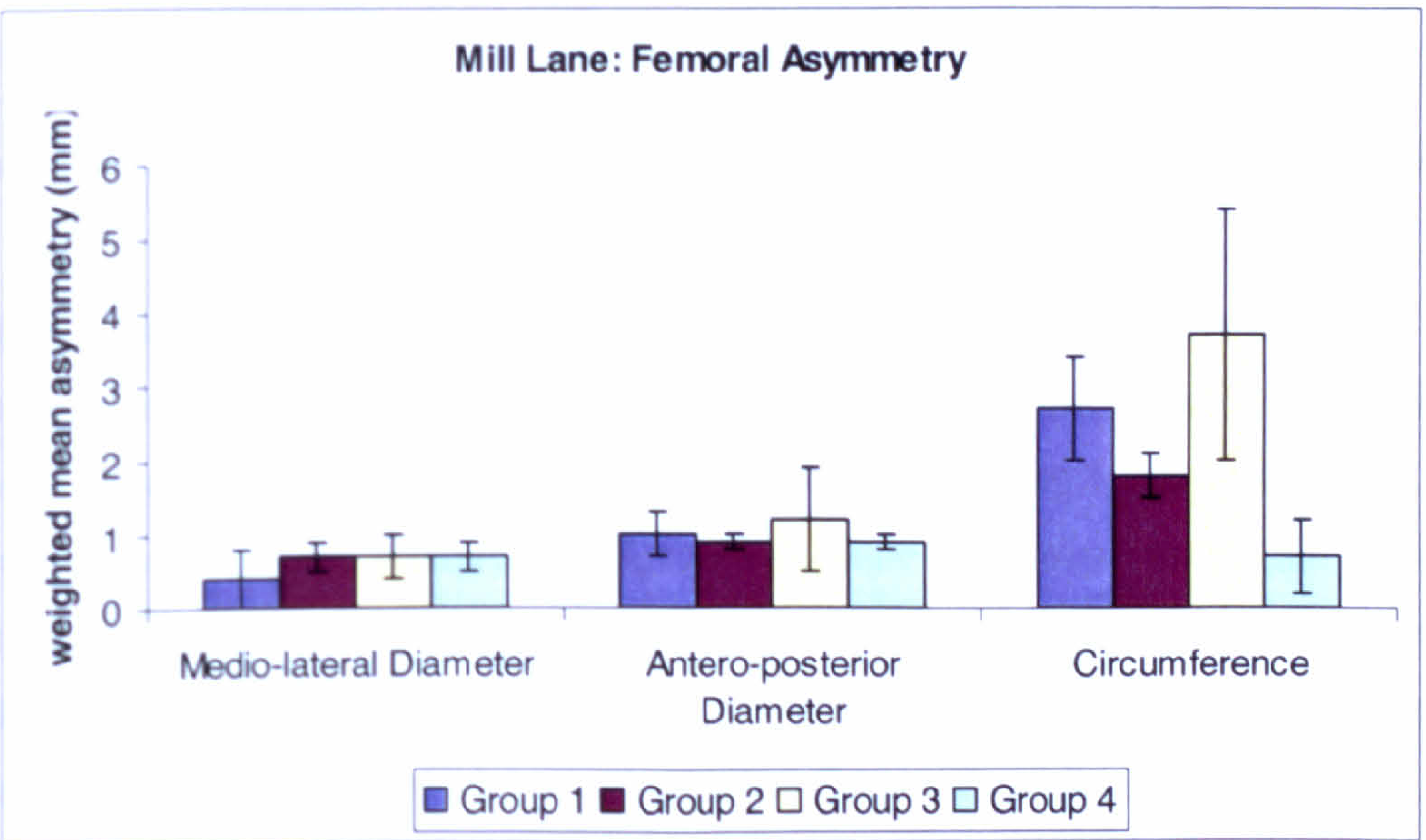


Figure 4.6.2c: The weighted mean absolute asymmetry of the femora in each of the artefact groups from Norton Mill Lane. Error bars - +/- SEM. Group 1 – No items or a single bead, potsherd or animal bone, Group 2 – A knife, with or without buckle or pin, one or more brooches/simple dress items, Group 3 – A weapon or weapons, Group 4 - knives, pins and personal items, dress items and jewellery.

In the medio-lateral and antero-posterior diameters of the femur the degree of asymmetry was very similar between the artefact groups. However, Group 3 had a slightly higher mean degree of asymmetry in the antero-posterior diameter and a much greater mean degree of asymmery in the circumference of the femur. When compared with all other males (Figure 4.6.2d) the degree of asymmetry in the circumference of the femora was significantly greater in Group 3 (ANOVA p=0.02)

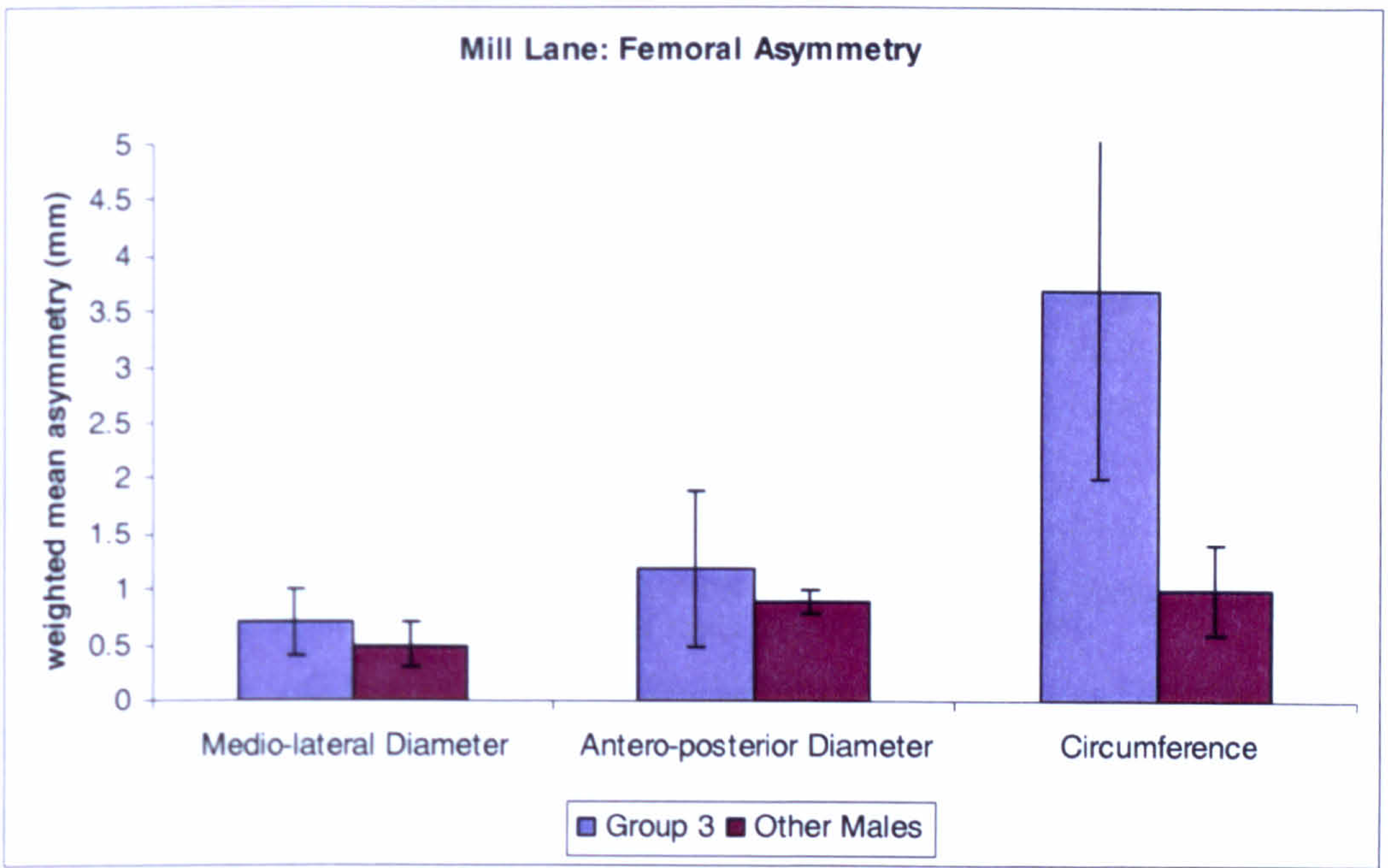


Figure 4.6.2d: The weighted mean absolute asymmetry of the femora from Group 3 and all other males from Castledyke South. Error bars - +/- SEM

In Figure 4.6.2c Group 4 appear to have low levels of mean asymmetry in the femur when compared with the other artefact groups all others. However, when the results for Group 4 were compared directly with all other individuals (Figure 4.6.2e), while the degree of asymmetry was relatively small, there was little difference between the degree of asymmetry in the medio-lateral and antero-posterior diameter. The difference between the degrees of asymmetry in the circumference was more striking, with Group 4 being on average much more symmetrical, but not significantly so (ANOVA p=0.8).

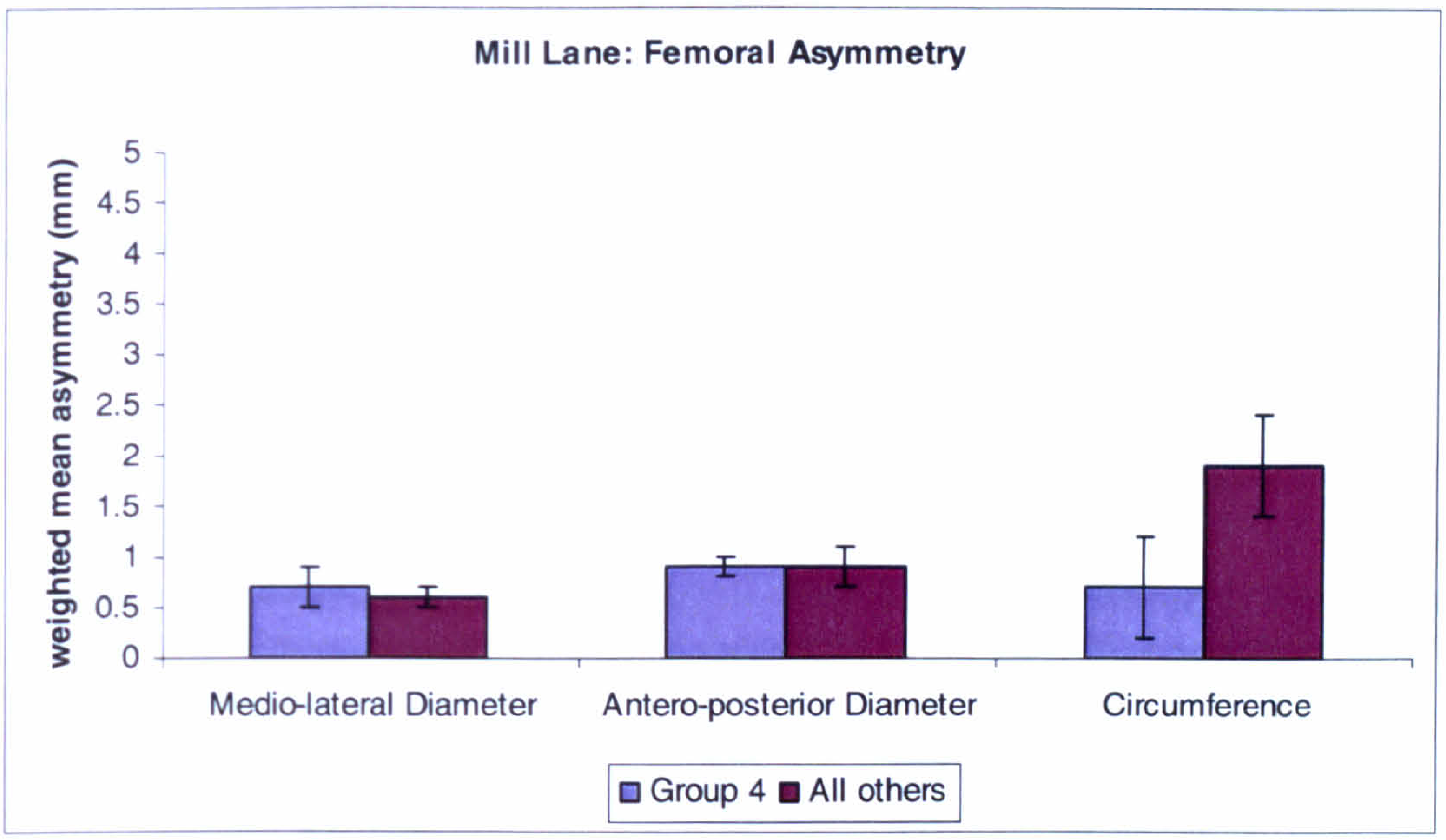


Figure 4.6.2e: The weighted mean absolute asymmetry of the femora from Group 3 and all other males from Castledyke South. Error bars - +/- SEM

These results suggest that Group 3 and Group 4 may have experienced different levels of physical stress in comparison with the other artefact groups, leading to differences in the degree of asymmetry seen in the humerus and femur.

4.6:3:Bamburgh

From the 40 individuals examined from the Bamburgh Bowl Hole sample, 14 pairs of humeri and 15 pairs of femora from females were measured to examine bilateral asymmetry, while 19 pairs of male humeri and 18 pairs of femora were measured. Table 4.6.3a shows the average difference, in millimetres, between the measurements of the right and left humeri (right minus left) in males and females, while Table 4.6.3b shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side). The larger the figure, the greater the degree of asymmetry in the measurements of the paired elements; if the figure is zero, there was no difference in the measurements of the two sides.

From these Tables it is apparent that the average difference in the right and left sides, and the difference in larger and smaller sides was greater in males than in females although this difference was not statistically significant (ANOVA right minus left: M/L p=0.7, A/P p=0.09, Circ p=0.6; absolute asymmetry: M/L p=0.4, A/P p=0.3, Circ p=0.3). The greatest degree of asymmetry was seen in the measurement of the circumference of the humerus. As all the figures in Table 4.6.3a were positive, this indicates that the right humerus was on average larger than the left side.

	M/L	A/P	Circ
Female	1.3	0.2	2.8
Male	1.5	0.9	3.3

Table 4.6.3a: Average difference in millimetres between the right and left sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

	M/L	A/P	Circ
Female	1.5	0.8	2.8
Male	1.9	1.1	3.6

Table 4.6.3b: Average difference in millimetres between the larger and smaller sides of the humerus in medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

Table 4.6.3c shows the average difference, in millimetres, between the measurements of the right and left femurs (right minus left) in males and females, while Table 4.6.3d shows the average absolute asymmetry from the femora of males and females from Bamburgh.

	M/L	A/P	Circ
Female	-1.1	-0.6	-2.2
Male	0	-0.2	-0.1

Table 4.6.3c: Average difference in millimetres between the right and left sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

	M/L	A/P	Circ
Female	1.5	0.9	2.6
Male	1.2	1.1	2

Table 4.6.3d: Average difference in millimetres between the larger and smaller sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

In Table 4.6.3c, the negative values indicate that on average the left element was larger than the right, in both males and females, and the average degree of asymmetry of the circumference was significantly greater in females than in males (ANOVA p= 0.01). Table 4.6.3d shows that in females, the difference in the medio-lateral diameter and the circumference was greater than that seen in the male femurs, but these differences were not statistically significant.

i) Asymmetry and Age

As with the other sites the reduction in sample size resulting from subdivision of the individuals into age groups necessitated the use of a weighted mean to account for any outlying data. As it has been established that the right humerus was generally larger than the left side, and that the left femur was generally larger than the right in both sexes, the following sections will only examine the absolute difference between the sides (larger side minus smaller side). Table 4.6.3e shows the average absolute asymmetry, in millimetres, in the paired humeri in each of the age groups, and the number of paired humeri measured in each group. As the number of individuals in the Young and Young/Middle age groups were small, these groups were combined.

Age Group	number	M/L	AP	Circ
Younger	7	2.4	0.4	3
Middle	9	1.1	1.1	3.1
Older	17	0.8	0.8	2.1

Table 4.6.3e:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in each of the age groups. Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

Although there was some variation in the mean degree of asymmetry, particularly in the medio-lateral diameter, this difference was not significant (ANOVA p=0.3), indicating that the degree of asymmetry in the humerus was not influenced by age.

Table 4.6.3f shows the average absolute asymmetry, in millimetres, in the paired femora in each of the age groups, and the number of paired femora measured in each group. The average asymmetry of all three measurements from the femur was similar between the age groups.

Age Group	number	M/L	AP	Circ
Younger	8	1.3	1.2	2
Middle	9	0.6	0.7	2
Older	15	1.6	0.6	2.3

Table 4.6.3f:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in each of the age groups. Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

Although the mean medio-lateral asymmetry was lower in the Middle aged adults than in the other individuals, this difference was not significant (ANOVA p= 0.1). As in the humerus, the absolute asymmetry of the femur was not influenced by age.

ii) Asymmetry and Status

Table 4.6.3g shows the average absolute asymmetry in millimetres for the three measurements of the paired humeri from each of the artefact groups, and the number of paired humeri measured in each group

Artefact Group	number	M/L	AP	Circ
Group A	15	1.2	0.7	3.4
Group B	7	1.2	1	3
Group C	6	1.2	0.6	1.9
Group D	5	2.4	1.3	3.4

Table 4.6.3g:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

The mean medio-lateral asymmetry was greatest in Group D, but the degree of asymmetry was the same in the other groups. The mean asymmetry of the circumference was smallest in Group C, as was the mean antero-posterior diameter. Figure 4.6.3a shows the weighted mean asymmetry of the humeri in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements. In this figure the differences between Group C, and particularly Group D individuals in comparison with the other groups is clear. Conversely, the results from Group A and Group B were homologous.

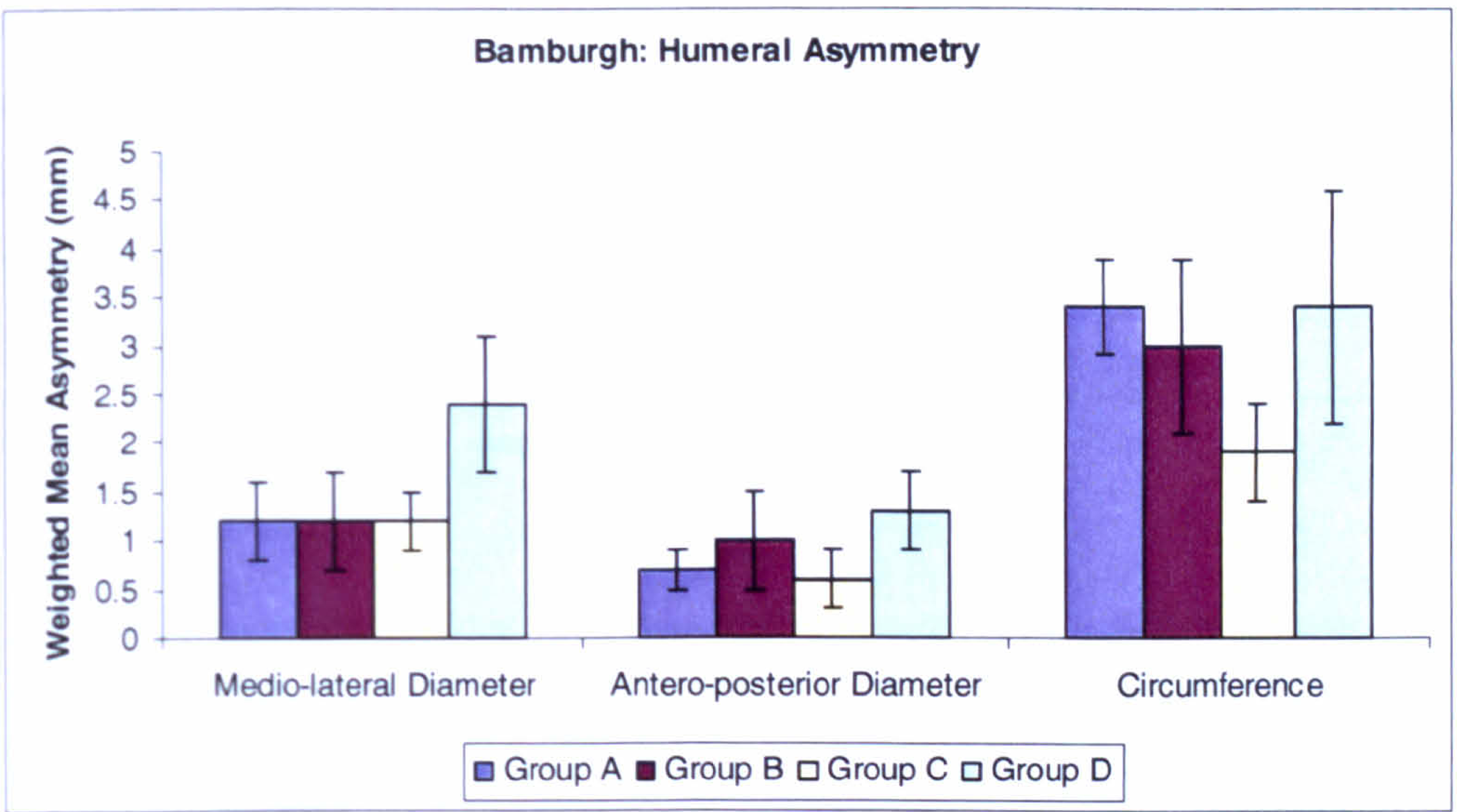


Figure 4.6.3a: The weighted mean absolute asymmetry of the humeri in each of the artefact groups from Bamburgh. Error bars - +/- SEM. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

As all of the individuals in Group C were male, and all but one of the Group D individuals were female, these two groups were compared with all other individuals of the same sex from the Bamburgh sample, to exclude the possibility that the differences in asymmetry were due to sex. Figure 4.6.3b shows the weighted mean asymmetry of the humeri from Group C and all other males, and Figure 4.6.3.c shows the results for Group D compared with all other females.

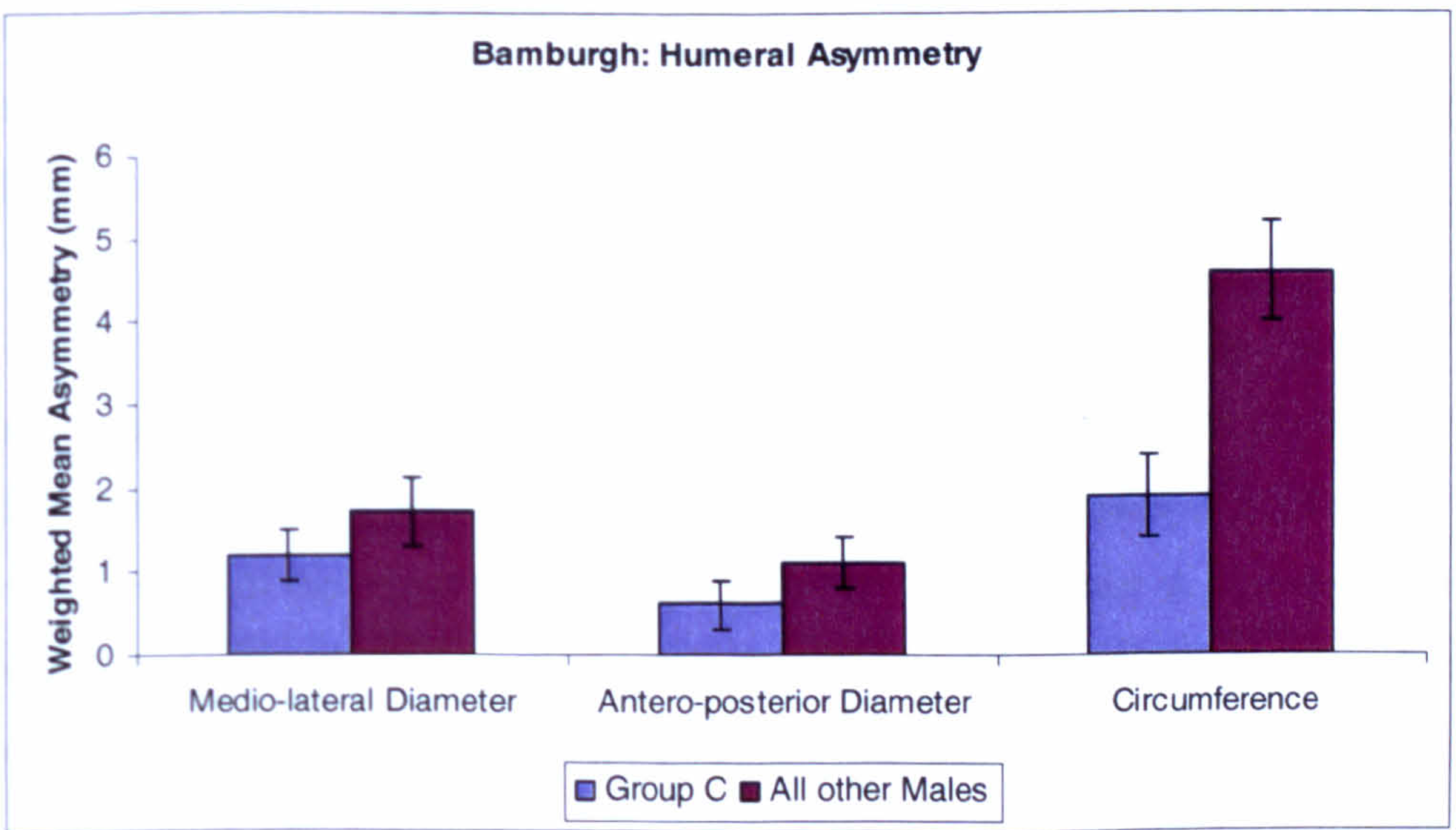


Figure 4.6.3b: The weighted mean absolute asymmetry of the humeri from Group C and all other males. Error bars - +/- SEM

Males from Group C were, on average, more symmetrical than all other males. All three measurements were smaller in Group C males, and the difference in the weighted mean asymmetry of the circumference of the humerus was significantly smaller in Group C males than in all other males from Bamburgh (ANOVA p=0.05).

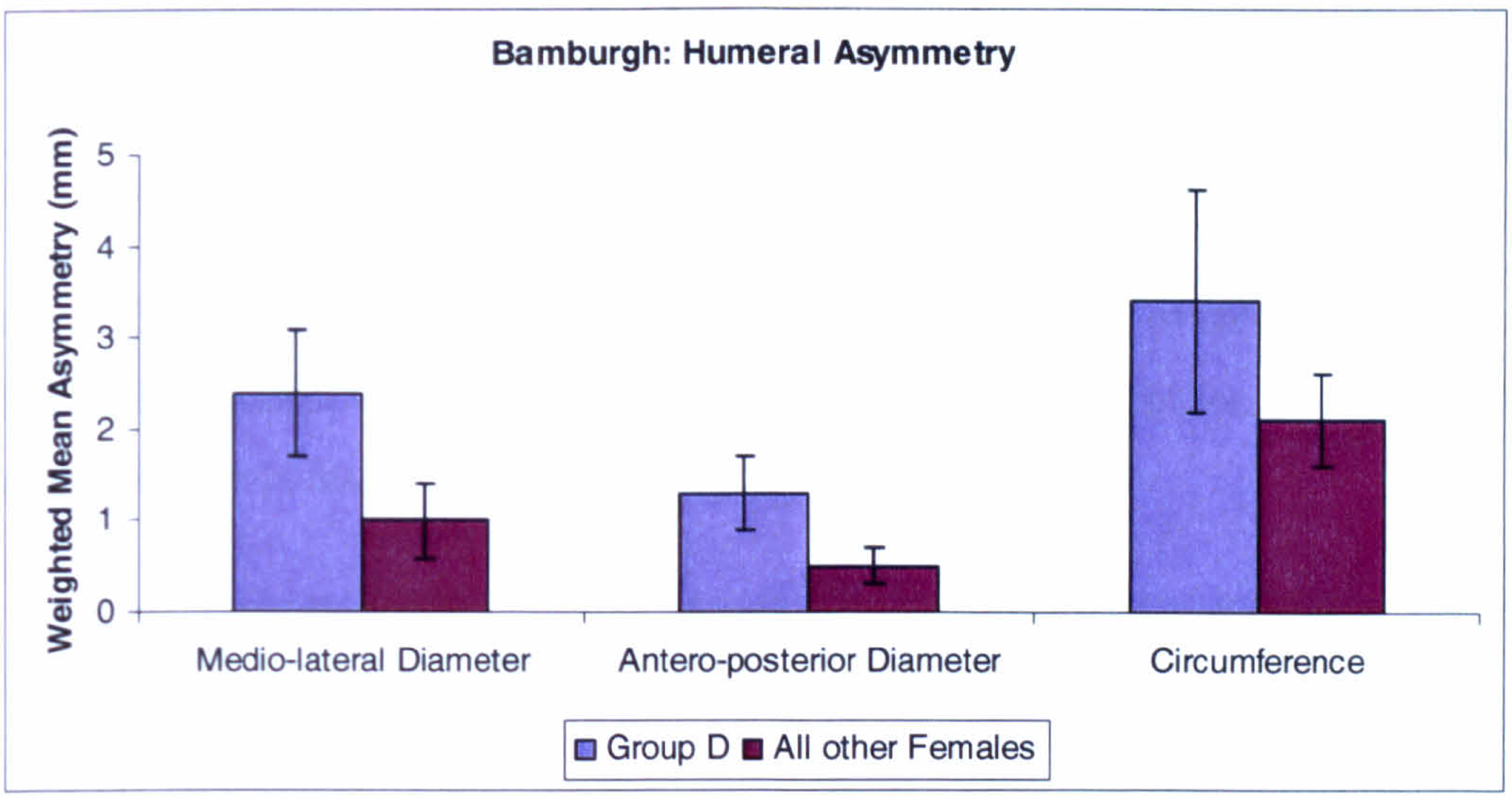


Figure 4.6.3c: The weighted mean absolute asymmetry of the humeri from Group D and all other females. Error bars - +/- SEM

In contrast, Group D individuals were on average more asymmetrical than all other females, in all three measurements from the humerus, although none were significantly different (ANOVA; M/L p= 0.3, A/P p= 0.3, circumference p = 0.2). These differences in the degree of asymmetry of the paired humeri suggest that there may have been a difference in the patterns of activity between Group C and all other males, and Group D and all other females.

Table 4.6.3h shows the average absolute asymmetry in millimetres for the three measurements of the paired femora from each of the artefact groups, and the number of paired femora measured in each group. As in the humerus, the degree of asymmetry in the circumference of the femur was smallest in Group C, and similar in the other three groups. Group C also had the smallest mean asymmetry of the medio-lateral diameter, but the greatest asymmetry of the antero-posterior diameter.

Artefact Group	number	M/L	AP	Circ
Group A	17	1.3	0.8	2.1
Group B	7	0.8	0.6	2.3
Group C	5	0.3	1.1	1.8
Group D	4	1.5	0.5	2

Table 4.6.3h:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

Figure 4.6.3d shows the weighted mean asymmetry in millimetres of the femora in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements.

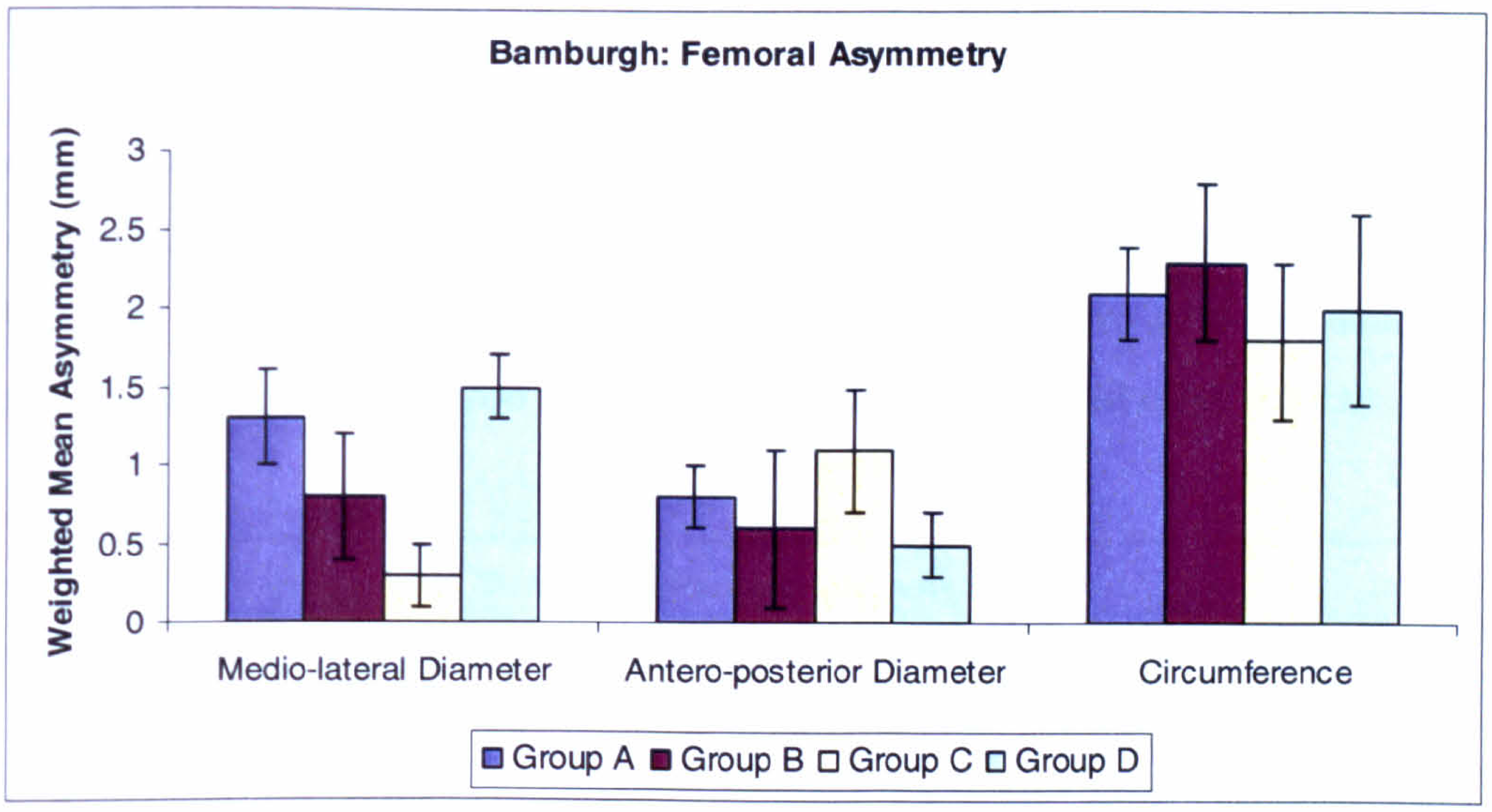


Figure 4.6.3d: The weighted mean absolute asymmetry of the femora from all four artefact groups at Bamburgh. Error bars - +/- SEM. Group A - no artefacts, Group B – single animal bone, tooth or shells, Group C –multiple animal bones, Group D – Multiple iron objects.

While the degrees of asymmetry in the circumference of the femur were quite similar between the artefact groups, there was more variation in the results for the medio-lateral diameter. For this measurement, Group C had on average the most symmetrical femora, and Group D were on average the most asymmetrical. As was seen in the results for the humeri, the results for Group A and Group B were quite similar to each other. Figures 4.6.3e and 4.6.3f show the results from Group C compared with all other males and Group D, in comparison with all other females.

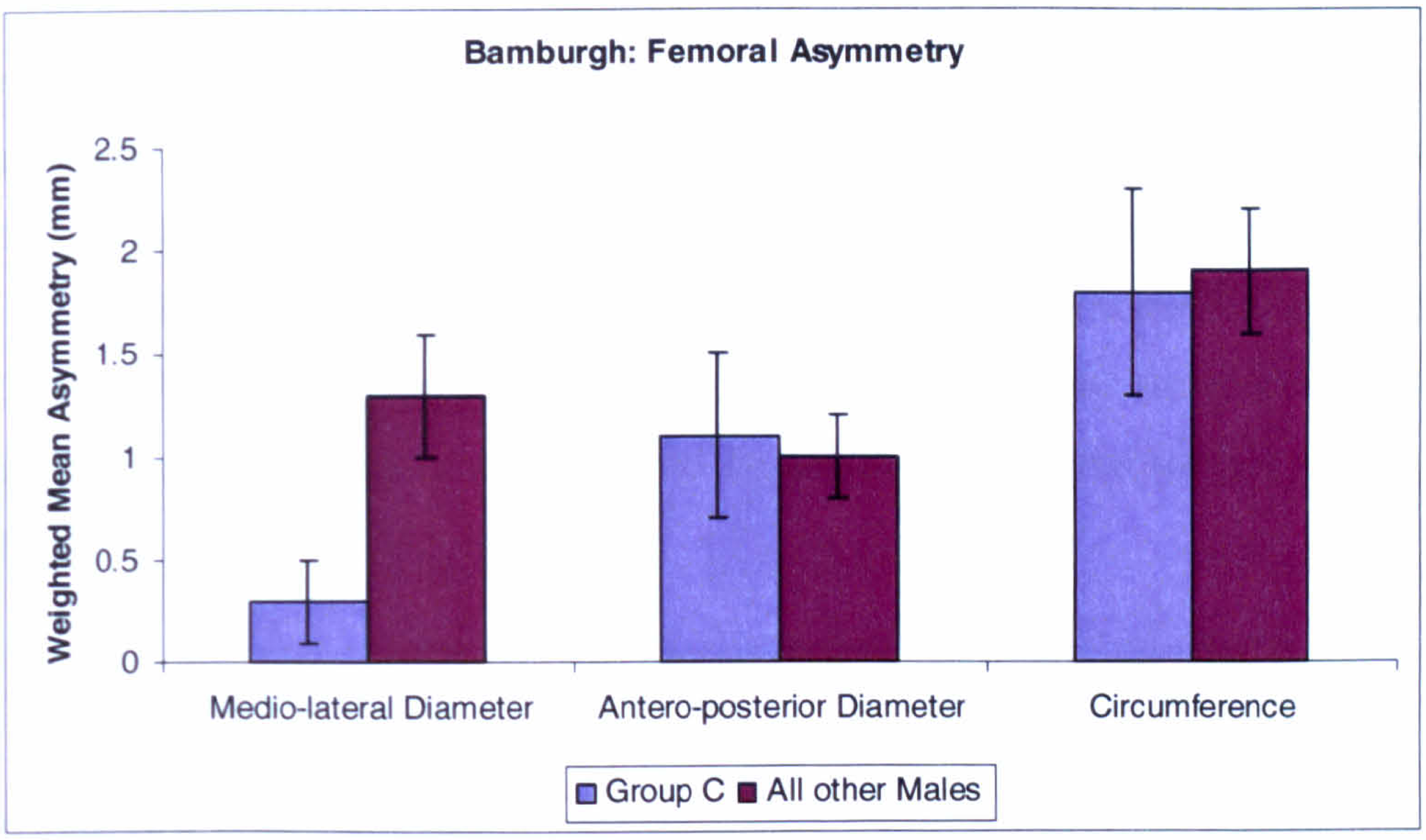


Figure 4.6.3e: The weighted mean absolute asymmetry of the femora from Group C and all other males. Error bars - +/- SEM

The degrees of asymmetry in the medio-lateral diameter and the circumference of the femora from Group C were smaller than those from all other males, but not significantly so (ANOVA; M/L p= 0.2, circumference p= 1), while in the antero-posterior diameter the Group C males were a little more asymmetrical on average than all other males.

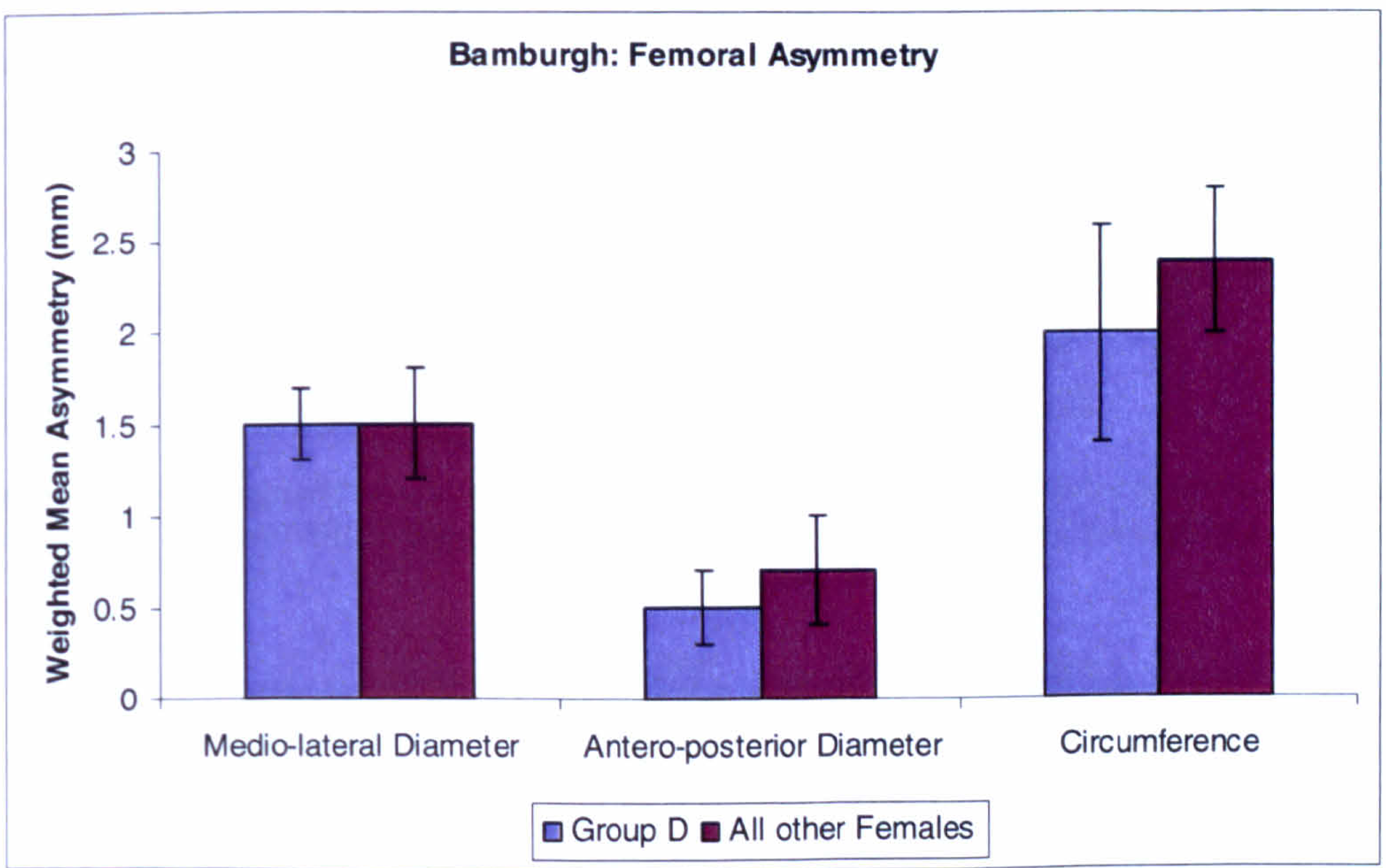


Figure 4.6.3f: The weighted mean absolute asymmetry of the femora from Group D and all other females. Error bars - +/- SEM

Although the results from Group D appeared to differ from the other artefact groups in Figure 4.6.3d, when compared with all other females these differences were not seen. The average degree of asymmetry in the medio-lateral diameter was the same as that seen in all other females, and although Group D individuals were slightly more symmetrical than all other females in the other two measurements, these differences were not significant (ANOVA A/P p= 0.4, circumference p= 0.4). These results suggest that there were no real differences in the levels of asymmetry in the femora between the artefact groups at Bamburgh.

4.6:4:Norton Bishopsmill

Of the 40 individuals examined from the Norton Bishopsmill skeletal sample, 10 pairs of humeri and 16 pairs of femurs from females were measured, while 12 pairs of humeri and 20 pairs of femurs were measured from males. Table 4.6.4a shows the average difference, in millimetres, between the measurements of the right and left humeri (right minus left) in males and females, while Table 4.6.4b shows the average difference in the measurements from the larger and smaller sides (larger side minus smaller side). The larger the figure, the greater the degree of asymmetry in the measurements of the paired elements; if the figure is zero, there was no difference in the measurements of the two sides.

	M/L	A/P	Circ
Female	1.1	0.6	2
Male	1.7	1.3	3.9

Table 4.6.4a: Average difference in millimetres between the right and left sides of the humerus in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

	M/L	A/P	Circ
Female	1.1	0.9	2.6
Male	1.8	1.5	4.3

Table 4.6.4b: Average difference in millimetres between the larger and smaller sides of the humerus in medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

The greatest degree of asymmetry was seen in the circumference of the humerus, in both sexes. All the figures in Table 4.6.4a were positive, indicating that on average the right humerus was larger than the left. For all measurements the degree of asymmetry was larger on average in males than in females, but not significantly so (ANOVA: M/L p= 0.3, A/P p = 0.4, circumference p= 0.2).

Table 4.6.4c shows the average difference, in millimetres, between the measurements of the right and left femurs (right minus left) in males and females, while Table 4.6.4d shows the average absolute asymmetry from the femora of males and females.

	M/L	A/P	Circ
Female	-0.1	-0.4	0
Male	-0.4	-0.2	0.3

Table 4.6.4c: Average difference in millimetres between the right and left sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

	M/L	A/P	Circ
Female	1	1.5	2.1
Male	1	1.1	2.6

Table 4.6.4d: Average difference in millimetres between the larger and smaller sides of the femur in the medio-lateral diameter (M/L), antero-posterior diameter (A/P) and circumference, (Circ) in males and females.

On average, the left femora were larger than the right in both males and females in both of the measurements of diameter, but the right side was marginally larger for the measurement of the circumference. There was very little difference in the average degree of asymmetry in the paired femora between males and females.

i) Asymmetry and Age

As with the other sites the reduction in sample size resulting from subdivision of the individuals into age groups necessitated the use of a weighted mean to account for any outlying data. As it has been established that the right humerus was generally larger than the left side, and that the left femur was generally larger than the right in both sexes, the following sections will only examine the absolute difference between the sides (larger side minus smaller side). Table 4.6.4e shows the average absolute asymmetry, in millimetres, in the paired humeri in each of the age groups, and the number of paired humeri measured in each group. As the number of individuals in the Young and Young/Middle age groups were small, these groups were combined.

Age Group	number	M/L	AP	Circ
Younger	7	0.9	1	3.5
Middle	6	1.3	0.6	2.3
Older	8	1.4	0.5	1.4

Table 4.6.4e:Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in each of the age groups. Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

While there was some variation in the weighted mean asymmetry of the humeri between the age groups, particularly in the circumference, these differences were not significant (ANOVA M/L $p = 0.5$, A/P = 0.9, circumference $p = 0.9$). Table 4.6.4f shows the average absolute asymmetry, in millimetres, in the paired femora in each of the age groups, and the number of paired femora measured in each group.

Age Group	number	M/L	AP	Circ
Younger	11	1.1	1.1	1.6
Middle	11	1	1.1	2.2
Older	12	0.9	1.3	2.3

Table 4.6.4f:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in each of the age groups. Younger = 17 to 30 years, Middle = 31- 40, Older = 41 + years.

As was seen in the paired humeri, there was very little difference in the mean degree of asymmetry between the age groups at Norton Bishopsmill, suggesting that age was not a factor in the development of asymmetry in either the humeri or the femora.

ii) Asymmetry and Status

Table 4.6.4g shows the average absolute asymmetry in millimetres for the three measurements of the paired humeri from each of the artefact groups, and the number of paired humeri measured in each group. At Norton Bishopsmill there were no individuals from Group C with paired humeri that could be measured, and the numbers of individuals in groups B and D were small, so in order to increase sample size the individuals without burial artefacts were compared with the combined results from groups B and D. Furthermore, the results from SK 217 (an Older adult male from artefact Group A) were excluded as the degree of asymmetry in the paired humeri from this individual was much greater than that seen in all other individuals.

Artefact Group	number	M/L	AP	Circ
Group A	13	1	0.4	2.5
Group B +D	8	1.3	1.2	2.9

Table 4.6.4g: Number of paired humeri and the weighted mean difference in millimetres between the larger and smaller sides of the humerus, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. Group A – no artefacts, Group B – animal bones or teeth, Group D – iron objects or coffin fittings.

Figure 4.6.4a shows the weighted mean asymmetry of the humeri in groups A and Groups B and D, with error bars showing the standard error of the mean for each group of measurements.

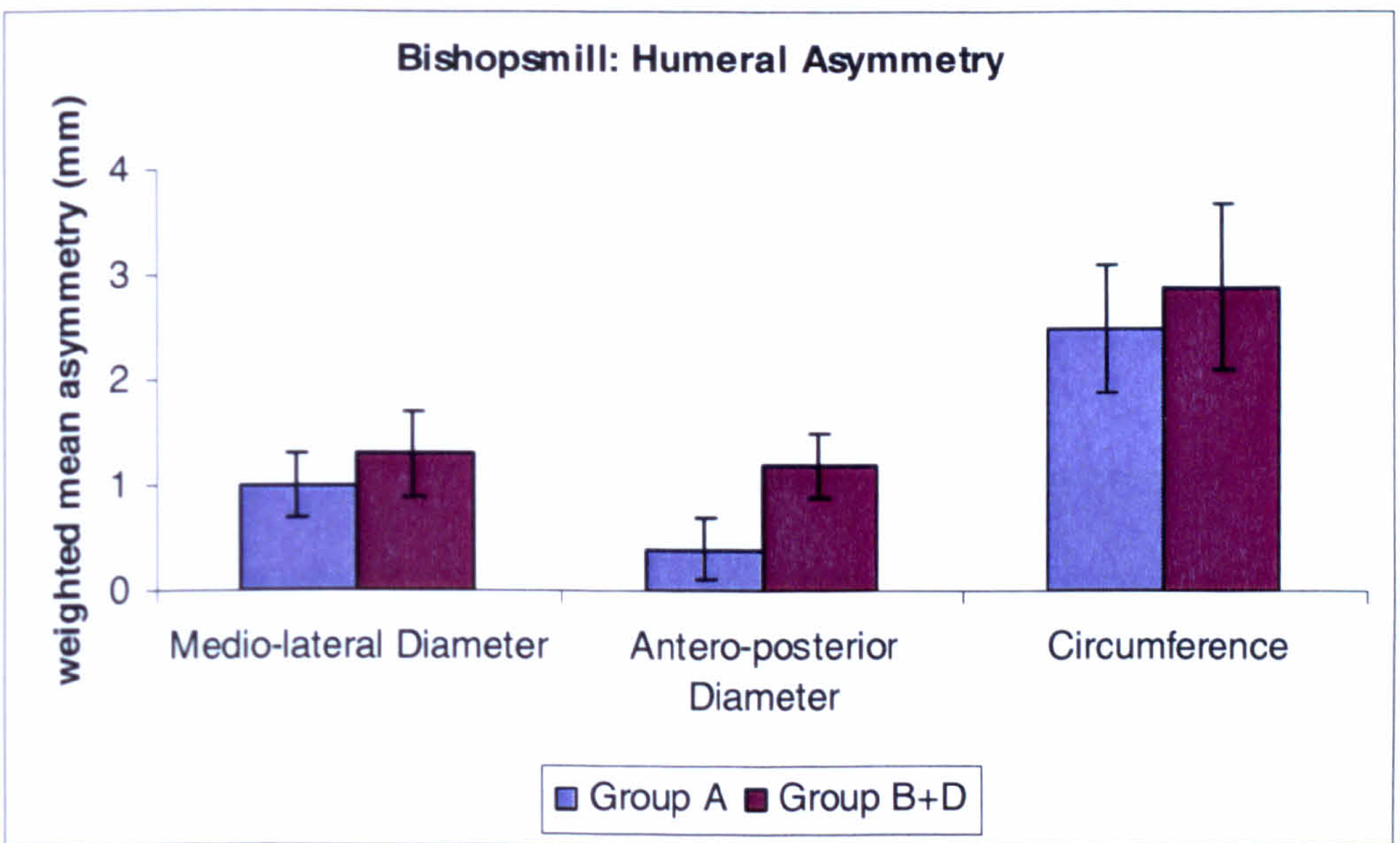


Figure 4.6.4a: The weighted mean absolute asymmetry of the humeri in each of the artefact groups from Norton Bishopsmill. Error bars - +/- SEM. Group A – no artefacts, Group B – animal bones or teeth, Group D – iron objects or coffin fittings.

Although the weighted mean asymmetry was less in Group A than in all other individuals from Norton Bishopsmill, in all three of the measurements, the difference was slight and not significant (ANOVA: M/L p = 0.3, A/P p= 0.8, circumference p=0.8).

Table 4.6.4h shows the average absolute asymmetry in millimetres for the three measurements of the paired femora from each of the artefact groups, and the number of paired femora measured in each group. As the number of individuals with paired femora suitable for examination from Groups B and C was small, the results from these artefacts were combined to increase sample size.

Artefact Group	number	M/L	AP	Circ
Group A	22	1	0.8	1.3
Group B +C	7	1	1.4	1.3
Group D	7	0.9	2	3.5

Table 4.6.4.h:Number of paired femora and the weighted mean difference in millimetres between the larger and smaller sides of the femur, in the medio-lateral and antero-posterior diameters and circumference in males and females in each of the artefact groups. Group A – no artefacts, Group B – animal bones or teeth, Group C – Pottery, worked stone or flint, Group D – iron objects or coffin fittings.

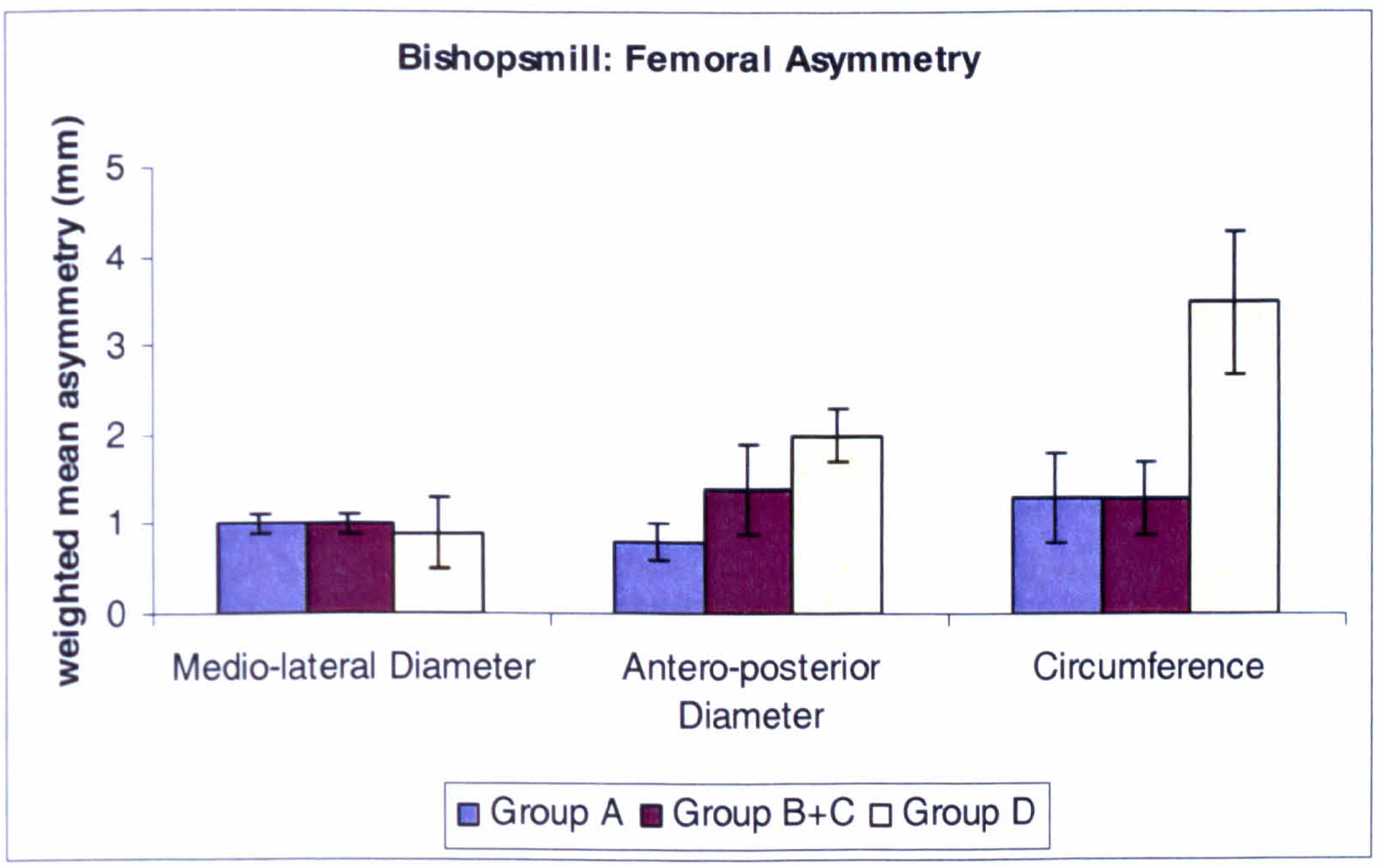


Figure 4.6.4b: The weighted mean absolute asymmetry of the femora from each of the artefact groups at Bishopsmill. Error bars - +/- SEM. Group A – no artefacts, Group B – animal bones or teeth, Group D – iron objects or coffin fittings.

Figure 4.6.4b shows the weighted mean asymmetry in millimetres of the femora in each of the artefact groups, with error bars showing the standard error of the mean for each group of measurements. It is clear from this figure that the degree of asymmetry of the antero-posterior diameter and the circumference in the paired femora from Group D was larger than that seen in the other artefact groups, and that the asymmetries in Group A and Group B and C were very similar.

Figure 4.6.4c shows the results from the femora from Group D compared with all other individuals from Norton Bishopsmill. When compared with all other individuals, the mean degree of asymmetry in the antero-posterior diameter and the circumference of the femur were significantly larger in Group D individuals (ANOVA A/P $p = 0.02$, circumference $p=0.01$).

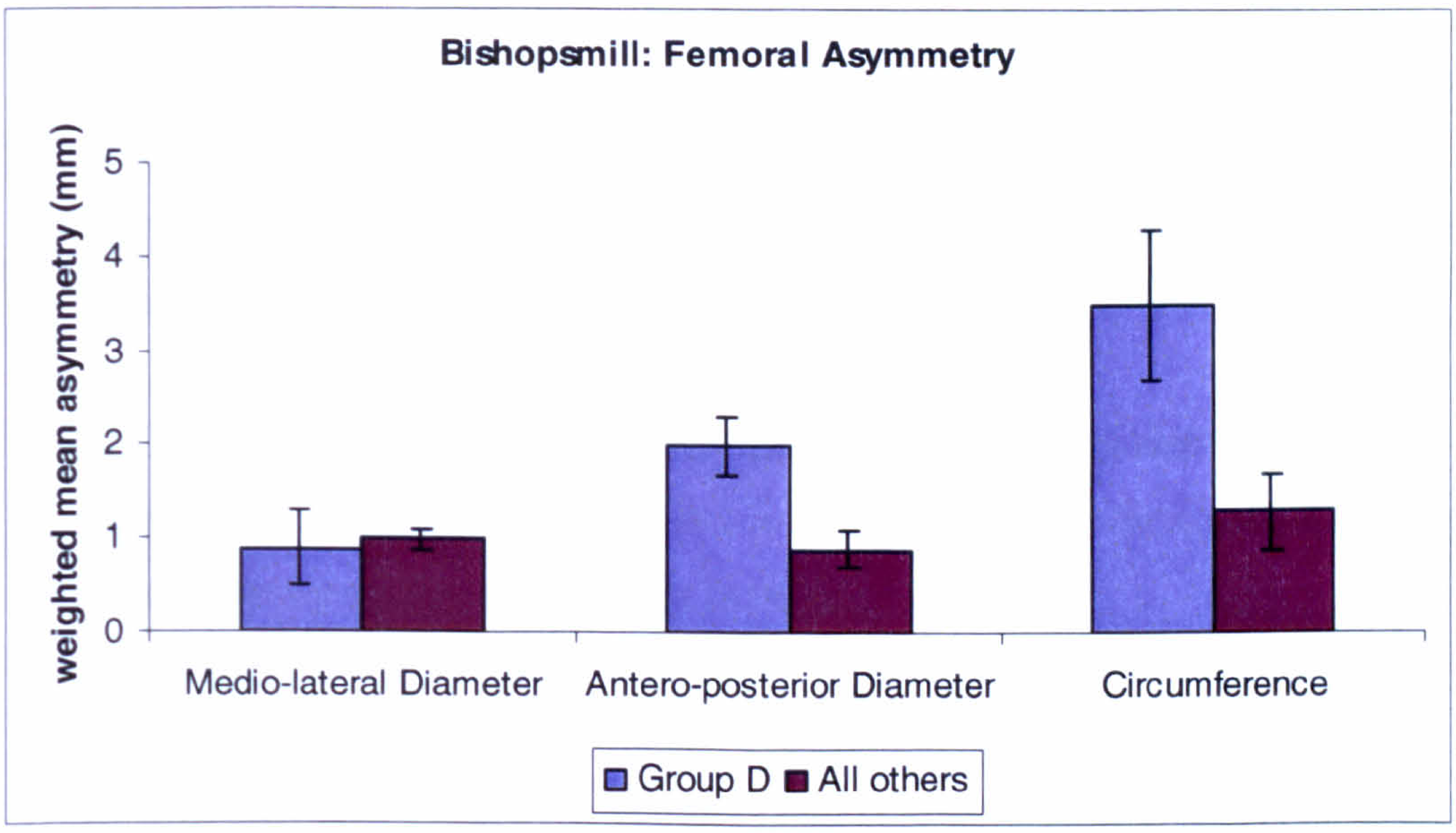


Figure 4.6.4c: The weighted mean absolute asymmetry of the femora from Group C and all other males. Error bars - +/- SEM

Although there was no difference between the artefact groups in the degree of asymmetry of the humerus, there were clearly substantial differences in the degree of asymmetry in the paired femora from Group D. As these differences were unlikely to be due to age or sex, it is possible that they represent differences in the patterns of musculoskeletal stress between the artefact groups.

Summary: Asymmetry

- In all four samples the measurements of the circumference showed the greatest degree of asymmetry in the paired humeri and femora. This may indicate that, of the three external measurements, the circumference gives the most reliable indication of the degree of asymmetry between paired humeri and femora.

- At all four sites, males generally had a greater degree of asymmetry than females in the humeri and femora, although the difference in the humeri was only significant at Castledyke and Norton Mill Lane.

- In all four samples the right humerus was generally larger than the left, while the left femur was generally larger than the right, which probably reflects the normal pattern of handedness.

- There was no significant difference in the degree of asymmetry between the age groups in any of the four samples, except in the Castledyke sample where the asymmetry of the humeral circumference was smallest in the Young/Middle age group.

- At Castledyke the paired humeri from Group 3 and Group 4 were more symmetrical when compared with sex-matched groups, but the Group 3 femora were more asymmetrical than those from other males.

- At Norton Mill Lane Group 3 humeri and femora were significantly more asymmetrical than those from all other males. Group 4 individuals had on average more symmetrical paired femora than all other individuals.

- At Bamburgh, Group C humeri were significantly more symmetrical than those from other males, while Group D humeri were more asymmetrical than all other females.

- At Norton Bishopsmill, Group A humeri were a little more symmetrical than all others, and Group D femora were significantly more asymmetrical than all other individuals.